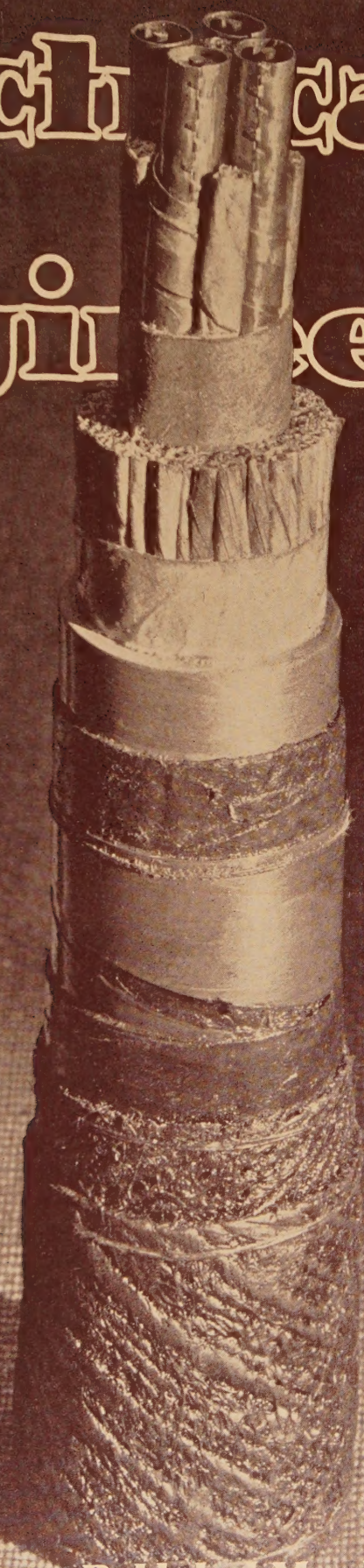


Electrical Engineering

February
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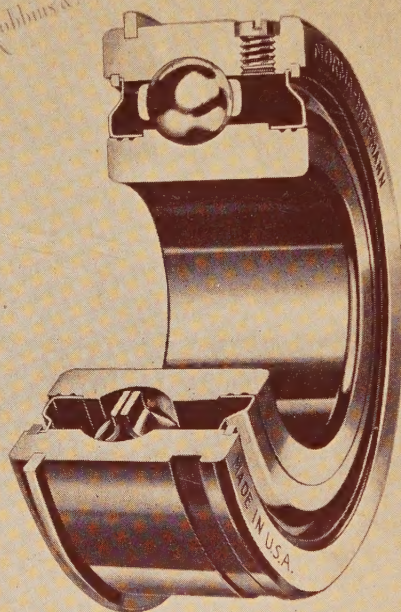
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Electrical Engineering

Registered U. S. Patent Office

for February 1941—

The Cover: Section of Stevens Point-Minneapolis coaxial cable, the first commercial cable of its type to be installed on the Bell System (see page 71)

Photo courtesy "Bell Laboratories Record"

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¶ Correspondence is invited on all controversial matters.

Motor-Performance Calculations. A method of calculating the performance of repulsion motors has been developed for the purpose of predetermining the torques and currents, especially for the starting period of repulsion-start induction-run motors (*Transactions* pages 67-73). A calculation sheet presenting the equations of capacitor-motor performance as developed by W. J. Morrill makes it possible to perform all the operations involved in calculating the currents, except the last, without the use of vectors (*Transactions* pages 73-6). The quantities necessary for calculating the performance of single-phase induction motors may be plotted as families of curves, by a time-saving method that eliminates the need of constructing a special diagram for each machine (*Transactions* pages 55-8).

Magnetic Storms. For many years magnetic storms, which occur at irregular intervals, have been known to disrupt all types of electrical communication systems; the storm of March 24, 1940, however, was so severe that it caused not only widely scattered disturbances on communication systems, but also operating difficulties on several electric-power systems in the United States and Canada (*pages* 72-5).

Artificial Respiration. A comprehensive study is being made of the pole-top method of artificial respiration, devised to give prompt aid in cases of electric shock; relative amounts of air moved by this method, the standard Schafer prone pressure method, and the modified Schafer method have been compared (*Transactions* pages 41-4).

Oilless Interrupter. Tests on a high-power circuit breaker using water as the interrupting medium have shown results comparable to an oil circuit breaker. Interrupters using water have already been used fairly extensively in moderate capacities (*Transactions* pages 85-8).

Capacitor-Motor Theory. The cross-field theory, heretofore applied to single-phase induction-motor analysis, has been extended to the capacitor motor; results of this and other analyses on the same motor have been tabulated for comparison (*Transactions* pages 58-62).

Overexciting Transformers. Measurements of harmonic voltages indicate that transformer exciting currents affect system-voltage wave shapes more than is commonly believed; the effects on wave shapes and power factor are discussed in this issue (*Transactions* pages 49-53).

Elevator Buffers. The speed at which an elevator buffer stops an out-of-control elevator at the bottom of its shaft must be limited for the safety of passengers; tests of the striking velocity have been made with a magnetic pickup coil and grooved iron rod (*Transactions* pages 53-4).

Resistance Welding. Improvements in controls and equipment for the various types of resistance welding have kept pace with the growing importance of this method of fabricating metals in modern high-speed industrial production. Recent developments are surveyed in this issue (*pages* 75-9).

Future Air Transportation. Greatly increased use of airplanes for cargo carrying is predicted in an article which urges immediate development of commercial aviation on a large scale because of its importance to the national defense program (*pages* 57-63).

Electric Shock. Results of experiments with a number of subjects provide much-needed information on the magnitude of current which human beings can withstand with reasonable safety; the authors also review the common effects of electric shock (*pages* 63-6).

Unbalanced Wye Circuits. Bringing together the many existing methods of solving three-phase systems with unbalanced wye-connected loads, an article in this issue compares the various methods and presents a numerical example of each type of solution (*pages* 80-5).

Electrical Governor. To control and regulate electrically the speed of hydraulic turbines, a form of frequency meter actuates a pilot valve which in turn controls the operating engine that opens or closes the wicket gates of the turbine (*Transactions* pages 80-4).

Winter Convention. The 1941 AIEE winter convention, in progress at Hotel Bellevue-Stratford, Philadelphia, Pa., January 27-31, as this issue goes to press, gave promise of record attendance (*page* 86). Full report of the convention will appear in the March issue.

Current-Limiting Fuse. To meet the demand for small totally enclosed fuses of high interrupting capacity for transformer protection, a new current-limiting fuse has been devised; tests confirm its reliability (*Transactions* pages 77-80).

Insulator Designs. Standard designs of pin-type switch and bus insulators and of suspension insulators have been analyzed in relation to the suggested requirements of "radio-free" insulators of these types (*Transactions* pages 62-6).

Utilities and War. Some of the problems created for utility companies by war and a war economy are discussed by an officer of a holding company with subsidiaries in the European war area and elsewhere (*pages* 67-71).

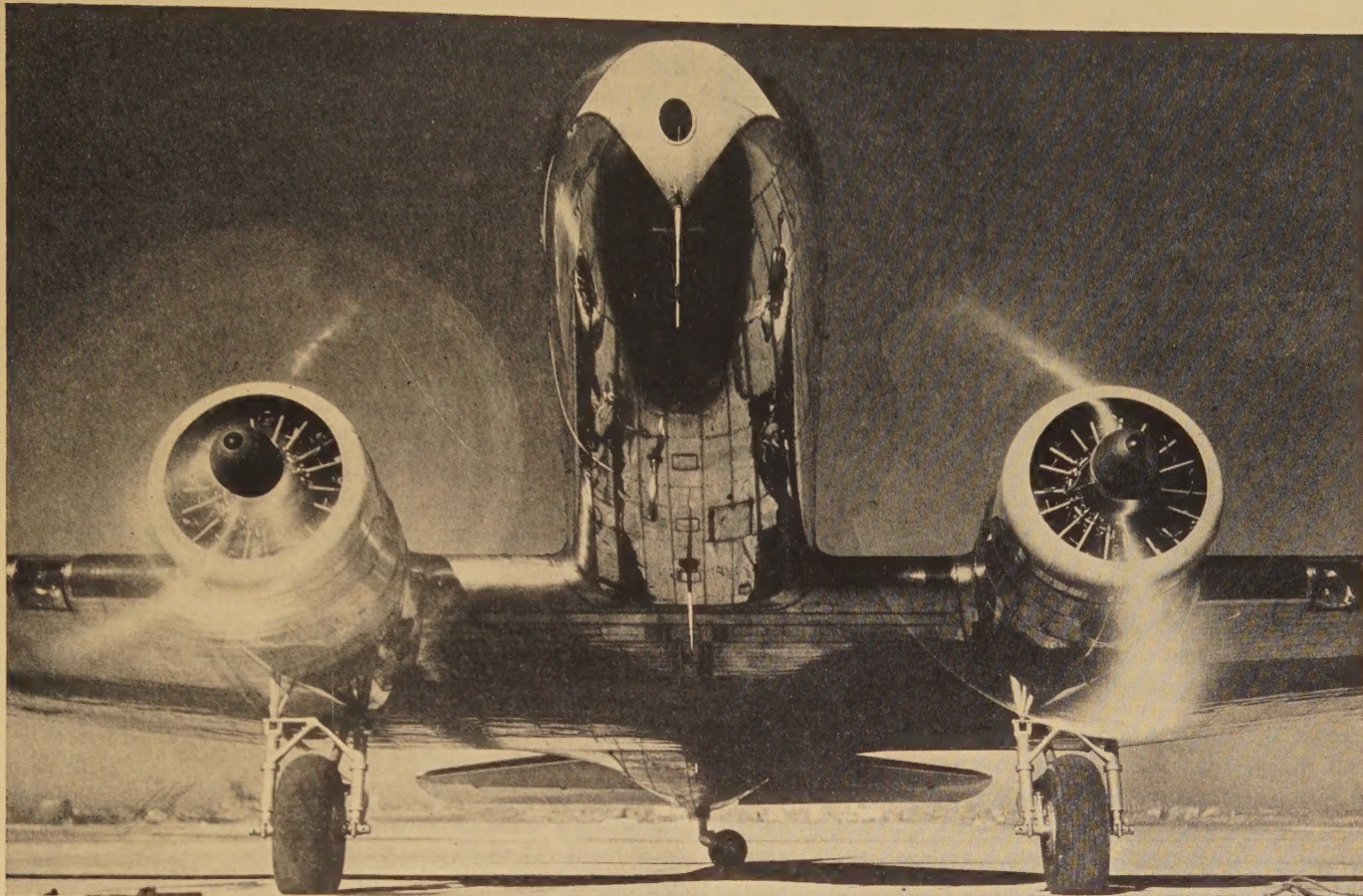
Point-Gap Behavior. Results of laboratory work on the behavior of point gaps at 60 cycles have been summarized for the benefit of those concerned with flashover of insulation or insulators (*Transactions* pages 44-8).

Correction. In the article "Trends in High-Intensity Mercury Lamps" by George A. Freeman, which appeared in the November 1940 issue, pages 444-7, the abscissa of figure 1 (*page* 445) should have read "Time—Minutes" instead of "Time—Seconds".

Coming Soon. Among special articles and technical papers currently in preparation for early publication are: an article on automatic control of aircraft by C. D. Barbulesco (M'40); an article on the technology of motion pictures by Douglas Shearer; an article on air-drome and aircraft lighting; an article on the challenge to industry that will come after the defense program by Charles E. Wilson; an article describing New York City's new Sixth Avenue subway; a paper on calculation of initial voltage breakdowns in air by D. W. Ver Planck (A'31); a paper on the d-c breakdown strength of air and of Freon in a uniform field of high pressure by J. G. Trump (A'31), F. J. Safford (A'35), and R. W. Cloud (A'39); a paper on the audio noise of transformers by W. C. Sealey (M'38); a paper on the automatic printing ammeter by T. G. LeClair (F'40); a paper on the minimum insulation level for lightning protection of medium voltage lines by H. M. Ekvall (A'27); a paper on the impulse and 60-cycle characteristics of driven grounds by P. L. Bellaschi (F'40); a paper on negative damping of electrical machinery by C. Concordia (M'37) and G. K. Carter (A'36); a paper on the analysis of short-circuit oscillograms by W. W. Kuyper (A'34); a paper describing a power-system governor sensitive to frequency and load by Thomas E. Curtis (A'40); a paper on picture transmission by submarine cable by J. W. Milnor (F'30); a paper on hollow-pipe transmission lines of relatively small dimensions by W. L. Barrow (M'33) and H. Schaevitz (A'40); a paper presenting a five-figure table of the Bessel function $I_0(x)$ by H. B. Dwight (F'26); and a paper on the electric strength of air at high pressure by H. H. Skilling (M'34) and W. C. Brenner (Enrolled Student).

Subscriptions—\$12 per year to United States, Mexico, Cuba, Porto Rico, Hawaii, Philippine Islands, Central and South America, Haiti, Spain, Spanish Colonies; \$13 to Canada; \$14 elsewhere. Single copy \$1.50. ¶Address changes must be received by the 15th of the month to be effective with the succeeding issue. Copies undelivered because of incorrect address cannot be replaced without charge. ¶ELECTRICAL ENGINEERING is indexed annually by the Institute, weekly and monthly by *Engineering Index*, and monthly by *Industrial Arts Index*; abstracted monthly by *Science Abstracts* (London). Copyright 1941 by the American Institute of Electrical Engineers. Printed in the United States of America. Number of copies this issue 24,100

Future Trends in Air Transportation



Courtesy American Airlines, Inc.

WITH the world at war today and ourselves at least in a very serious emergency phase as a result, the attention of the aviation world, and of those in other fields who are interested in aviation, concentrates so heavily on the military airplane as an offensive war weapon only that we lose an important perspective. The airplane that does not carry any guns or bombs or have any lethal fighting power is also a war weapon, and it is a war weapon of such great importance that we are fully justified in stepping into the war picture with our plea for commercial aviation and its development even in the midst of the roar of guns.

America, in the last ten years, has achieved an outstanding superiority over the rest of the world in the development by private initiative of its commercial air system.

GROVER LOENING

Considering commercial aviation in relation to national defense now, and its own potentialities in the future, a pioneer aircraft builder and aviator and well-known aeronautical consultant here outlines a program for the development of cargo transportation by air. Because of the immediate and vital importance of the subject, the conclusions of this expert are particularly significant; comments are invited.

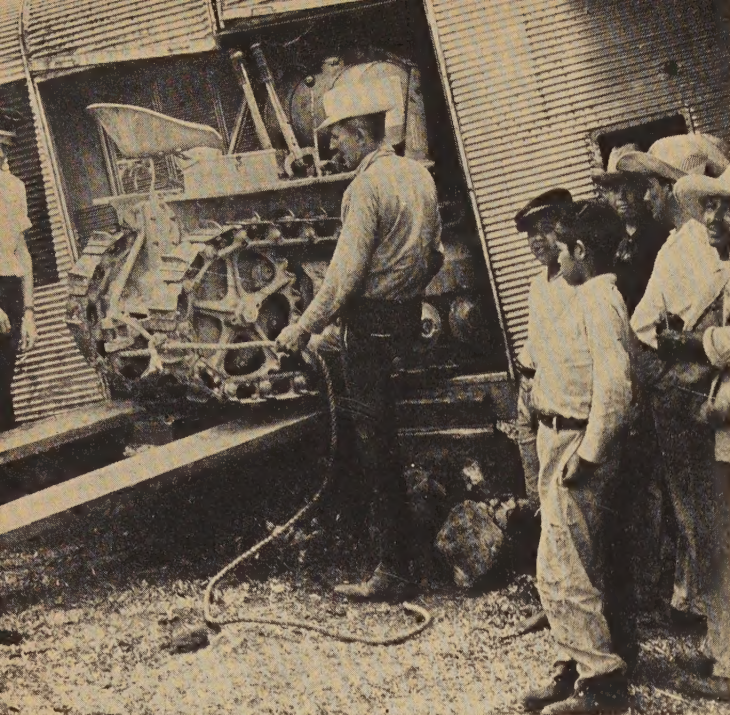
found this extraordinary proof: In the United States, throughout its entire commercial air system, both domestic and overseas, not one single airplane engine, propeller, instrument, or in fact any accessory was of foreign manufacture. There are, in fact, practically no foreign-made privately owned airplanes in the air in the United States. And what have we elsewhere? American airplanes, American engines, American propellers, and countless American developments were purchased by and in the use of the airlines of every other major nation in the world. To land on a foreign airport in August 1939 was to see an array of Douglasses, Lockheeds, Stinsons, Fairchilds; American engines, American propellers, and American developments

American airlines are longer, faster, more used, better equipped, more far-flung, and far more efficient than the airlines of any other country were just prior to the present war. This is due to our competitive system and that alone.

The development of passenger-carrying and privately owned airplanes in this country had become so superior to that of any other country that we

An address delivered at a joint meeting of the New York Electrical Society and the transportation group of the AIEE New York Section, New York, N. Y., January 8, 1941.

GROVER LOENING, B.Sc., A.M., C.E., consulting engineer, is chairman of the board of the Platt-LePage Aircraft Corporation, and also of Roosevelt Field.



Using specially rebuilt planes, the TACA Company transports heavy freight to and from Central American locations

almost as familiar as on one of our own domestic fields. But this priceless advantage is threatened by the supposed exigency of war—threatened by the military mind, acting in its traditional way with perfectly good intent, in all honesty and in all sincerity, but without understanding the value of what might be lost.

It is proposed, therefore, to look at the military lessons to date, to look at the immediate war value of commercial air transport equipment, and to take a peek into the future in order to give a layman and civilian appraisal of why we can claim immediate war-making value to our present commercial aviation setup.

Aviation has always been a strange business—if one can call it a business. Capable men of vast experience who are unfamiliar with aviation are recorded again and again as making in regard to it the gravest errors in judgment.

The industry itself starts out with the greatest of difficulties because from its very inception it is a constant fight of opposing factors. We must build as strong as we can to stand the racking stresses in the air and yet we have no weight with which to incorporate that strength. We must build our planes as speedy as we can to be useful in competition and yet by the same stroke of the drafting pen we must make them as slow as we can in order to be safe in landing. We must produce in tremendous quantities at once with production machinery and yet in the very midst of this we must be able to change instantly in order to meet a new development.

Aircraft production is very different from automobile production. The last war proved it conclusively and this war will repeat the performance. The automobile producer has to learn an entirely new lesson in relation to aircraft, a lesson which the aircraft producer already knows, and that is how to produce in quantity with facility for

vital construction changes. The aircraft man knows that a second-rate airplane—no matter how many thousands there are—is of no value.

It is probably these limitations constantly surrounding aircraft development that make it unique, and hence so difficult to understand and judge for those not born and bred in it. Marshal Foch, toward the end of the last war, was told one day by a group of his officers that various aviation difficulties had arisen and had created a crisis. He calmly replied, "A crisis—in aviation there is always a crisis." Our field is better summed up by this statement: In aviation there are no steps in the ladder to success; there are only tightropes.

MILITARY TRANSPORT OF TROOPS

Now let us consider the war. We find the usual lessons, of course—heavier armament, more lethal arms, more performance, more production, more intensive training, and so forth, all in the usual progressive ratio of development that new arms give rise to. In this war we have found one outstanding lesson not heretofore made evident and made only too tragically potent by it. That is the use of aircraft as a transport.

A first instance occurred in the Spanish Civil War when Franco flew his troops from Morocco into Spain. Subsequently, the Hitler Gestapo troops that took control of Vienna, having been stalled on bad Austrian roads, were then carried by commandeered air transport and landed on the Aspen airport. We finally lead up through interesting indications from maneuvers to the lesson taught to the world when Germany occupied Norway. It was air transport more than any one thing that made this occupation possible, military students now agree. The Germans suddenly showed the world that they did not need control of the water between Denmark and Norway when they proceeded to land some 30,000 troops by air at Oslo in a couple of days. Then they went along for months on their campaign, dropping parachute troops here, ammunition there, and guns on the tops of mountains. Finally they even recovered the captured port of Narvik by supplying practically everything needed by air.

So now we have opened a new path for war. Formerly the infantry could laboriously trudge, fight, dig itself in, worm its way through on the ground to its enemy. Then the navy could sweep through the seas and hide itself under the seas and use all the various floating devices to carry itself and its needed munitions to its objective. But now we can vault over the strongest navy in the world and the strongest land army holding a ground position. An air force can laugh at both and blithely jump over to an objective, take, feed it, and ammunition it, with utter contempt for what is on the ground or on the water between.

How does this apply to the United States? It applies more powerfully than to any other nation because we are a nation with distant possessions and distant outposts made so very much nearer by air. Hawaii is only 12 hours from California; Panama is only 6 hours from Florida; Puerto Rico is even less; and Alaska is only 3 to 4 hours from Seattle. What is much more important, New York is only 12 hours from California. But this closely knit

proximity of American points of importance is meaningless unless we have the planes with which to get there and back. That is where our merchant marine of the air assumes commanding importance.

There is a considerable trend on the part of government authorities—and a very natural one—toward feeling that in time of war our commercial airlines should be shut down or taken over. A thorough understanding of what a serious blow this would be to our air strength for war, many of us feel, will surely change this point of view.

Our airlines have developed a highly organized system of maintenance, dispatching, traffic control, etc., that allows for present vast operation of aircraft in commerce. And this operation is very different from Army aviation, as proved by Army experience in trying to fly the air mail in 1934. We have some 400 fast well-equipped modern commercial airliners in service in the United States. As long as these planes are within the confines of the United States or its possessions, they are as much the property of the Army or the Navy as if they were in those services, because they can be commandeered tomorrow morning. And their crews are all trained and ready.

The big lesson to be learned from the war is that they should be commandeered now and then, at least for practice. Last summer some three or four hundred thousand soldiers were moved around the United States in various maneuvers. Not one of these operations was done by air, although private operators had offered their services. In August of 1940 a garrison of 700 troops was sent from New York to Alaska. They were sent on the Army transport St. Mihiel and it took them about 30 days to get there. Right there an opportunity was missed to show what we could do by air. If the government had commandeered 40 or 50 airliners from the various airlines, those troops could have been transported from New York to Alaska in less than 24 hours! Because of the fact that the airliners are in operation, the planes maintained, and the crews on their toes—and they are in the air night and day—they could have been commandeered and found of immediate use at extremely short notice.

Fortunately, the war lesson is being learned. The Army at present is training infantry for air-transport operation. In the present Army Douglas C-39 transport 4,000 pounds can be carried and in tests at Fort Benning, Ga., 37-millimeter antitank guns have been loaded on these planes. As a result of the tests there and at Fort Sam Houston, it has been shown that a war-strength infantry battalion with complete arms and ammunition and other supplies for several days can be transported in 50 airplanes of the ordinary standard type, providing that 4 of these are modified to two-door type to accommodate the infantry battalion guns.

Viewed in the light of war production of planes our fleet of 400 transport planes is not very impressive. There are many suggestions for increasing it. First is the frequently made suggestion that first-class mail be sent by air. According to Captain Edward Rickenbacker, who has extensively considered these possibilities, 10,000 additional air transport planes would be required and 40,000 pilots and co-pilots as compared to the 2,000 pilots that we have



More first-class mail could be sent by air

at present. Such an operation would carry 75 per cent of the annual 350,000,000 pounds of first-class mail.

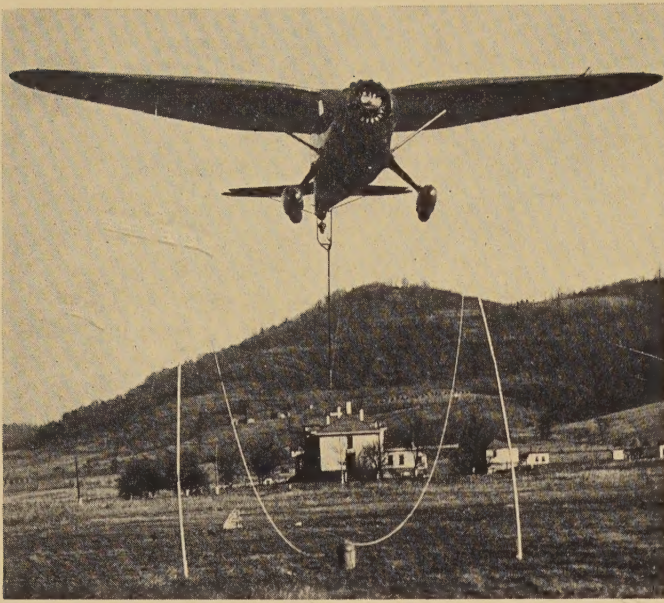
Three-cent letters average about 32 to the pound; the income, therefore, is 96 cents a pound. A passenger and baggage average about 200 pounds, and at the same rate a passenger could be carried the same distance the mail is carried for \$192. However, the average passenger distance traveled in the United States is about 600 miles, and for that distance the fare is about \$30 (5 cents a mile). It follows, therefore, that the income from a passenger is considerably less per pound than it would be for 3-cent mail.

If the Post Office Department were to pay 2 of the 3 cents to the airlines, they would make plenty of money and we would have plenty of commercial airplanes available as a reserve for a war emergency.

Another suggestion has been made, which is that we develop the carrying of cargo by air. We will look into this in more detail later.

If, therefore, various suggested means of obtaining a faster growth in air transport were to be expedited immediately, our fleet would grow accordingly until finally we would have so many air transport planes in use in the United States, ready for instant service when called, that we could seriously consider transporting 100,000 troops to Panama, Puerto Rico, Alaska, or Hawaii, whenever we wanted to.

In other words the American Expeditionary Force of the future—and the very near future—is likely to be air-borne, not water-borne. The Leviathan of that era will not be the slow fat ship that the Germans let us take, but more like the new Douglas bomber, the giant new aircraft ordered by the Army, the B-19 that will weigh very nearly



All-American Aviation plane using a new type of equipment to make a pickup at New Martinsville, W. Va.

170,000 pounds gross. It can, with its four engines, carry up to 125 armed troops with complete equipment 3,000 miles nonstop. It can haul 18 tons on short ranges. It can carry 11,000 gallons of gasoline. It is capable of a non-stop maximum range of 7,500 miles and could fly a non-stop round trip to Japan from an Alaska base.

With planes of this type it would be possible to concentrate ten Army divisions in Florida and with a fleet of 1,000 such giant aircraft transfer them to points on the Brazilian coast 3,000 miles away in about 15 hours. Well over 100,000 troops spirited from this country for the protection of a neighbor overnight—this is what the future of troop and ammunitions transport will permit when we finally organize a real air force for this country.

TRANSPORT OF CARGO

Now let us take the next important consideration—the transportation of bulk cargo by air. At first glance most people dismiss aircraft as a serious load carrier. But we know now what we may safely predict to an incredulous world, that will learn only after a lapse of a few years that we were right. Bricks, cement, steel beams, and all other manner of goods will be carted around the skyways of the United States by air at 300 miles per hour in the coming decade, because it will be so cheap, despite the speed!

The facts of 1940 indicate this and the least we can do is to look at them. A modern trailer truck carrying an average of 10- to 12-ton loads, using a 100-odd horsepower engine and a two-man crew, will travel on our magnificent roads at an average of 25 to 35 miles per hour day and night, including necessary stops. The costs of trucking vary considerably, but a general average shows that cargo movement in these vehicles will cost somewhere around 3 cents a ton-mile and the average charge for this service runs up to 4 cents a ton-mile, the rate varying, of course, on different articles. These large tractor trucks cover about five miles to the gallon of gasoline and the cost of

operation, including depreciation, is roughly 21 cents a mile.

The truck companies that operate between Florida and New York and other parts of the north generally carry north agricultural products, citrus fruits, etc. On the return trips they carry anything from a bird cage to a cannon. They carry furniture, ladies' dresses, and all kinds of merchandise.

Because of the number of itinerant truckers (the privately owned subterfuge to avoid regulations) the total amount of truck traffic between Florida and the north is difficult to estimate, but it runs to several million pounds a day. With the advent of real cargo-carrying planes—of which there are several in the United States fully tested and in production, some of us rather timidly a short while ago began to compare their cost with that of trucking. We were rather startled.

Among the best developed of these planes today is the Douglas C-39 cargo transport which is used by the Army. One of the older types which was very successful was the Curtiss Condor, now very widely used in South America. Cargo versions of the Lockheed and Douglas and other airliners are in wide use all over the world. The latest entry into this field, now in production, is the Curtiss-Wright C-20. This plane weighs 45,000 pounds. It is powered by two Wright 1,500 horsepower engines. It can carry a load of well over 16,000 pounds (8 tons). This load can be carried a nonstop distance of 800 miles at a cruising speed of 215 miles per hour.

What is still more important is that the C-20 has a cargo-capacity volume of 2,760 cubic feet. That is just about the volume of a freight car, which is a little under 3,000 cubic feet. The freight car can carry between 20 and 30 tons, while the cargo plane carries 8 tons.

Once and for all then, we have settled the dispute over the question of space. In cargo-carrying planes there is more space per ton for the cargo to be carried than in freight cars or trucks.

The greatest development of cargo carrying by air has been achieved in Central America by the TACA Company, now a division of American Export Airlines. This company does a gross business of more than 30,000,000 pounds a year, carrying everything from merchandise, food, and machinery to bulk ores, chicle, and even livestock. Regions otherwise wholly inaccessible are provisioned by air freight exclusively.

An example is illuminating. Let us say we wish to carry 800 tons of cargo from New York to Miami in two weeks' time. By more or less continuous going, night and day, trailer trucks can make a round trip between Miami and New York within a week, so that we would have two round trips per truck required, and since we have to carry 400 tons on each trip, and each truck carries 10 or so tons, we would need about 40 trucks. An airplane at 200 miles an hour, including one brief stop for fuel, will cover the distance from New York to Miami in six hours, and with a suitable number of hours for turn-around and maintenance could make ten round trips a week. One airplane of the C-20 type carrying 8 tons each trip in two weeks' time will transport 160 of our 800 tons of cargo. So to carry the

800 tons in two weeks' time we would need only 5 cargo-carrying planes instead of 40 trucks.

The purpose of this example, of course, is to show that the airplane, light and small as it is, is a load carrier by virtue of its speed and consequent ability to build up ton-miles quickly. Where the bulk of the freight car and the truck are impressive as load carriers, the "to-ing and fro-ing" done by the airplane must be envisioned to appreciate its load-carrying possibilities.

When we take into account the cost of gas per ton-mile, operating costs, taxes, depreciation, etc., we find for a cargo plane of this type a direct cost of 5.3 cents a ton-mile and a charge of about 8 cents a ton-mile with overhead and profit proportional to those of the trucking system.

All the items in a typical load of a trailer truck can be carried in cargo aircraft existing today, at a cost only slightly more than twice the cost of heavy trailer trucking. Then, too, they can be carried at a speed almost ten times as great as that of trucking, which brings in other economies to balance the cost.

From this we can estimate that if air cargo planes are carried up in size—which they most certainly will be—to a gross weight of 200,000 pounds and the ability to carry a pay load of 40 tons, their cost of operation will be down to under 4 cents a ton-mile. That is why some of us are able to predict to you where we are heading in this business. The 300 mile-per-hour airplane of the future literally is going to take business away from the dray horse, because it is cheaper despite the fact that it is so much faster.

PRESENT-DAY LIMITATIONS

Of course there are limitations to this air cargo development. First is the fact that due to the war exigencies, the authorities in Washington do not feel that equipment can be released for cargo-carrying development because it is needed for war. That is why it is so important to impress upon everyone that the development of a vast air cargo system in this country is absolutely a preparation for war and in fact one of the most needed of all. There is no use having long-range operations of bombers and air bases if we cannot supply them.

The next limitation is of course airports. The airplane must have its field. The airports generally are removed from the factories and big centers of industry and inconvenient transshipments that are costly and time-consuming are necessary. But do not dismiss this too quickly as a fundamental handicap, because the aviation industry is going to surprise you.

To begin with, the general tempo of business is such that executives, government officials, engineers, etc., fly to and from their business appointments and will continue to require enormous amounts of passenger air transport. Passenger air transport is already 17 per cent of Pullman traffic and will increase as additional airports become available. Not only are many more airports being built by the government but many large private companies are contemplating having their own fields at their factories. But we recognize that this is not enough, so what we have up our sleeve is beginning to be evident.

The first development we have in actual service—successfully demonstrated and now already in wide use—is the air pickup system. This makes the roof of every large factory a potential station for the transfer of air cargo. An airplane lets down a hook that snares a line to which is attached a package, weighing up to 100 pounds, and draws it up into the airplane, without landing. Deliveries are made in a similar manner by dropping the cargo in special containers by parachute. While air pickup today, in two years, has progressed only to small loads—largely mail and a little express—there is nothing technically to prevent its further development into much heavier units. Even today one aviation company, All-American Aviation, Inc., is operating in ten states with 108 stations.

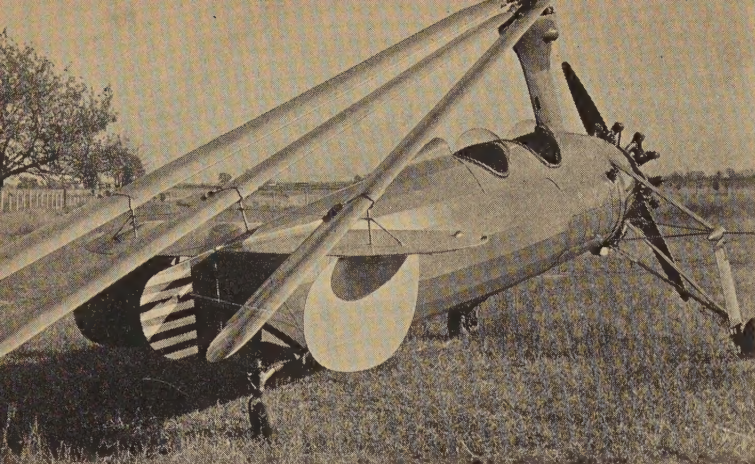
Next come the aeronautical engineers tackling the most difficult technical construction problem that the industry has faced in its entire history—the development of the helicopter. This is the type of aircraft that lifts and lands vertically, doing away with the landing-field limitations of air transports, and making every large level roof or tennis-court-size strip of lawn a perfectly good landing field. We are at the threshold of this development—at the threshold of having in the air helicopters that will lift a ton. In the dim future they may gradually catch up with the load-carrying plane of many tons.

Third, our engineers are covering a lot of new paper with designs for the final development we need, which is to carry on the cargo liner a small delivery-truck tender in the form of a slow-landing plane or helicopter that will take off from the back of the big plane, land or pick up its cargo, and return into the air from any location where cargo is available. The latter, of course, is in the distant future, but is the directly indicated development of the "picka-back" plane that has been demonstrated so successfully on trans-Atlantic flying and may still have a very broad influence on war design. In particular, its design is likely to be expedited by the necessity of long-range bombers carrying their little fighter planes within them and launching them when they get to an objective thousands of miles away. This suggests clearly the prospect of large cargo-carrying transcontinental planes making pickups and deliveries at small intermediate stations by the use of auxiliary planes.

These various future considerations lead us to a very important conclusion, which is: Limitations of aircraft resulting from their inability to make local pickups and deliveries are going to disappear, so that we end with an air vehicle for transporting cargo from anywhere to anywhere else, and doing so at speeds that cannot be even

A Focke-Achgelis helicopter taking off





Army YG-1 autogiro, Kellett Autogiro Corporation

approached by terrestrial or water means of transportation.

THE REALITIES

Let us leave this fascinating future for the moment to look at the realities. Why have we so little cargo carrying in the air in the United States?

The reason is simple. Believe it or not, air cargo carrying in the United States is a monopoly owned by the railroads—a fact generally not known. The 70 major railroad systems of the country own the Railway Express Agency. This company has with each airline exclusive contracts containing the following items: First, no express or freight forwarding or delivery company except the Railway Express Agency can handle air cargo for the airline—suggestive of a clear monopoly. Second—no rates can be made less than twice that charged on the railroads—a clear suggestion of price-fixing. Actually the air rates are held at five to seven times railroad rates.

The Railway Express Agency does a gross business of some \$170,000,000 a year. Of this the Air Express business is a little over \$2,500,000 a year—about 1.5 per cent. At the time these contracts were made, they were no doubt justified. But our whole system of carrying cargo in the air started out wrong and has never been able to achieve any serious proportions. Obviously, of course, the high rates are the principal reason. Actual Air Express rates at present average 80 cents a ton-mile, which is from 5 to 7 times higher than Railway Express rates.

We mentioned earlier that cargo planes could be run at about 8 to 10 cents a ton-mile. Actually, Railway Express rates—not Air Express rates but ordinary railway rates—run from 10 to 15 cents a ton-mile. So today we have proof that aircraft can carry express for less than the rate for express carried on the railroads, if done in enough volume.

In the month of October 1940 the passenger carrying on the domestic airlines totaled up to the amazing amount of 116,000,000 passenger-miles. Since the passenger and his luggage average 200 pounds, the number of passenger-pound-miles carried by the airlines totaled 23,200,000,000 pound-miles. During this same month the air mail that was moved amounted to 1,894,000,000 pound-miles. But the express cargo carrying on all the airlines that month amounted to only 731,000,000 pound-miles, or less

than 3 per cent of the gross for the airlines for that particular month. The revenue from passengers for that month was \$5,800,000 and the revenue from mail was \$1,700,000. The revenue from express was \$365,000. As a typical example, we can take United Air Lines, which earned a gross during that month of \$1,692,000. Of that gross, the gross income from the carriage of express cargo was only \$91,000.

The express companies and the airlines announced that this year Air Express business has increased 30 per cent. That sounds big, but it really means an increase from 3 per cent to 3.9 per cent of the total traffic. With potentialities, the business should increase from 3 per cent to 80 per cent—a volume more proportionate to what cargo earnings are in other transportation systems.

The only justification that can be found for the railway setup is that the Railway Express Agency furnishes a pickup and delivery service. But, as has been indicated, air developments taking place right now will eliminate the necessity for much of this. The railways and the trucking companies can no more stop the steady and inevitable advent of air carriage into the transportation field than they can stop the sun from rising by hanging on to the hands of the clock.

SPEEDING UP DEFENSE

We have still to consider the most potent immediate reason for a vast extension of air-cargo carrying. That is its use in speeding up construction of aircraft and munitions for defense.

Most major aircraft factories have their own flying fields right at their doors. Further, in the present rush to produce aircraft in great quantities a great deal of subcontracting is being done by these large aircraft plants. I quote a recent press release showing government recognition of the importance of this "farming out".

"Explaining the farming-out principle, the War Department declared that that principle is rapidly becoming important in this country as a means of breaking up defense contracts so as to bring into use reserves of idle equipment. As the defense program continues to put an ever-increasing burden on large manufacturing facilities, the expedient of using small units of production will be resorted to more and more...."

The Undersecretary of War, Judge Robert B. Patterson, has pointed out how very important the small machine-shop operator is in the defense scheme and that the "farming-out" of orders would have the effect of preventing too great migration of workers and of forestalling housing shortages. But the prime contractor must still take full responsibility in selecting his own subcontractors. With a cargo air service operating between the various main contractors all over the country and with a pickup service capable of handling small units, the scope of the prime contractor is immensely increased, with a consequent general speeding-up of his entire production. For example, the Glenn Martin Company, at Baltimore, Md., has a 3,500 ton press, useful for large operations in airplane manufacture, and a machine tool hard to duplicate in present defense congestion. With sufficiently fast cross-transportation between aircraft factories, this press could

be used to press out material for other manufacturers who do not have such a machine. And for trouble-shooting, the wide use throughout the country in this munition emergency of the quick shipment of needed parts by air would save literally millions of man-hours of labor before the end of the year.

Little do we realize the magnitude the air industry itself is attaining until we look over the results to date. The Bureau of Labor Statistics indicates that the 203,000 workers in aircraft factories in October 1940 will have to be increased to 455,000 by October 1941. When accessory establishments in addition are included, the grand total of employment in sight for the fall of 1941 in the aircraft business is 555,000 workers! This means that within the year the aircraft industry will become almost the largest employer of factory labor in the country, while two years ago it was almost an insignificant industry so far as employment was concerned. In September 1939 the nation's leading aircraft factories had a total of 9,000,000 square feet of working floor space. By November 1940 this working area had been increased to 17,000,000 square feet. By 1942, when the present expansion programs are completed, the industry will have grown to 33,000,000 square feet.

To this industry the addition of a comprehensive air cargo transport system would be the simplest kind of development, because the airfields are already at its doors

and all those connected with it are completely air-minded, and as a result munitions-making would be enormously speeded up.

At the end of this emergency, the enormous production facilities that will have been developed will need a market, and no market will be more tempting than that of cargo carrying by air.

We may forecast here, therefore, a tremendous era of rivalry and intensive competition and a lowering of rates. Load-carrying planes, bombers, etc., delivered into a second-hand market status, will be used for the carriage of all manner of goods, and flown by all manner of ex-war pilots, to a degree that might lead to as much confusion as there is now in the trucking business if we do not undertake at once to organize it along much more manageable lines.

The immediate development of cargo carrying by air in great quantities is thus seen to be a defense measure, and in fact one of the greatest contributions that the air industry can make to the nation's defense. Not only would it provide a fleet of planes available at a moment's call to defend the country by carrying troops and munitions to our possessions and outposts, but by speeding up transportation would hasten production of munitions. Carriage of air cargo, therefore, must be regarded as one of the most important of the new developments crying for immediate attention today.

Effects of Electric Current on Man

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With increasing use of electric fences, insect screens, and other devices having exposed electrodes, information on the magnitude of electric current that is safe for human beings becomes of great importance in determining regulations and safety codes. The authors report the results of experiments showing the maximum 60-cycle alternating current and direct current which the average man can withstand with reasonable safety.

THE danger of exposure to electric shock has been increased by the widespread use of devices having exposed electrodes, such as the electric fence, the electric insect trap, the electric fly screen, and the electric cattle prod. Many of these devices are purchased and installed by persons who are not familiar with the principles involved or the dangers inherent in such apparatus. Because of the simplicity of construction, convenience, and

economy afforded by the electric fence, many types are offered by small manufacturers or constructed by novices with little or no regard for safety. Some of the homemade varieties are energized directly from lighting circuits protected only by ordinary fuses. In others the current is limited to about 62.5 milliamperes with a $7\frac{1}{2}$ watt incandescent light. More elaborate devices have been constructed using radio parts and thermostatic interrupters. The authors recently tested one of these devices and found that the interrupter failed in the energized position when a resistor equivalent to the human body resistance was connected to the fence terminals. Many of these devices have proved unreliable or ineffective, and have caused numerous animal fatalities. Quite recently regulations governing some of these devices have been adopted,^{1,2,3} but the issue is far from being closed.⁴

Several human deaths have been caused by contact with electric fences,^{5,6} and in the light of existing conditions it

Based upon a paper "Electric Shock" by the authors and J. L. Thurston, presented at the AIEE winter convention, January 27-31, 1941, Philadelphia, Pa. Research was aided by a grant from the California Committee on the Relationship of Electricity to Agriculture. The authors wish to express their gratitude to the many men who volunteered for the experiments, which could not have been conducted without their co-operation and continued interest. The authors are indebted to J. L. Thurston, C. J. Manner, J. R. Burch, and S. H. Robley, students in electrical engineering, for their assistance in obtaining and analyzing the data.

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1. For all numbered references, see list at end of paper.



Figure 1. One of the test subjects at his 60-cycle let-go current

is indeed surprising that the number of fatalities has been so small. While some regulations have been adopted, the preparation of adequate regulations and the formation of safety codes have been impeded by lack of scientific information as to the amount of current that is safe for man. In the interest of public safety, it is essential that legislation be provided to permit only the sale and use of *approved* devices.* The public must be protected against the purchase of dangerous products.

An investigation of the energy requirements and safety of electric insect traps, undertaken by one of the authors in 1936, showed that no reliable information was available on currents required to control animals or to kill insects. Of much greater importance, there was little information available on the magnitude of electric currents safe for man. Therefore the original scope of the problem was expanded to include a study of the general effects of electric shock on man. This paper presents results obtained on direct current and 60-cycle alternating current. (For details of the experimental procedure, data, curves, and statistical analysis, see reference 12.)

A brief review of the effects of power-frequency currents on man may prove interesting and instructive. The threshold of perception is about one milliamperes when electrodes are held in the hands. A very faint tingling sensation is first felt. This rapidly increases in intensity as the current is increased, and at the same time involuntary muscular contractions of the hand and wrist appear. These in-

crease in intensity and progress up the arm to the chest with currents of 10 to 15 milliamperes. From 15 to 20 milliamperes the muscle contractions are severe and painful, and a sensation of mental discomfort difficult to describe may appear. At 20 milliamperes or higher, the chest muscles become involved, and breathing becomes somewhat difficult. Up to a certain point an individual can still release the electrified wire in spite of the involuntary muscular contractions. The authors have called the highest current at which muscular control is still possible the "let-go current".

The main object of our investigation was to determine the let-go currents of a large number of subjects. Of the 114 men tested on 60-cycle alternating current, the average let-go current was 15.5 milliamperes, and the highest was 21.6 milliamperes. In order to get an accurate determination, it was necessary to go above the let-go current of each individual. However, none of the subjects was given more than 2 or 3 milliamperes in excess of his value. What happens at values slightly above this is conjecture, at least as far as the authors are concerned. The subjects were exposed to the current for a matter of seconds only, just sufficient to give them time to exert a determined muscular effort. This exposure is distinctly in contrast with that of individuals who grasp an electrified wire and have to endure it until aid reaches them. The effects of fear must play an important role in these instances. The tetanic contraction of the chest muscles might be sufficient to interfere greatly with breathing, and after sufficient exhaustion from muscular effort, death might occur from asphyxiation. Currents in excess of those that cause involuntary cessation of breathing, due to effects on the muscles, are believed to result in temporary paralysis of the nerve centers which may paralyze the respiration for a considerable period of time even after interruption of the current.^{7,8} Somewhat higher currents cause ventricular fibrillation, which results in death due to failure of the heart muscle. The minimum current necessary to produce ventricular fibrillation in man has been estimated to be about 100 milliamperes for shock durations of three seconds or longer.⁸ Once the human heart muscles begin to fibrillate, little can be done to save the victim. Currents considerably in excess of this value cause violent contractions of the body musculature, and are believed to suspend the action of the heart, instead of causing it to fibrillate.⁹ The heart may resume its normal rhythm upon interruption of the current, or it may do so if resuscitation measures are applied promptly. Relatively large currents (amperes, *not* milliamperes) produce sufficient heat to destroy nerves, muscle, and bone and to cause hemorrhages. Major damage to vital organs, especially that resulting from electric arcing, may be so severe that death is inevitable. Delayed death may be due to burns, hemorrhages, or other complications.

In many high-voltage accidents the combination of high contact resistances and severe muscular reactions results in limited currents of short duration. These may cause respiratory paralysis and cessation of breathing. The heart may continue to beat, it may fibrillate, or, which is more likely, it may come to a standstill. Thereupon

*"Approved" means approved, labeled, or listed as conforming to the standards of the National Bureau of Standards, the Underwriters' Laboratories, Inc., the United States Bureau of Mines, or other similar institutions of recognized standing.

unconsciousness and apparent death occur. However in many instances the victim may be saved. Since a layman cannot distinguish between these various possibilities, he should immediately give the victim artificial resuscitation. This should be continued until death is diagnosed by a physician, until *rigor mortis* sets in, until the body becomes cold, or until the victim revives. The value of the Schafer prone-pressure method or the newer pole-top method of resuscitation^{10,11} must be emphasized, especially to men in the field. Nevertheless, the best means of reducing the present fatality rate of about one in 100,000 is instruction in the proper procedures for electrical workers, education of the public in the use of electrical equipment, and rigid adherence to safety codes. It is encouraging to note that only a very small percentage of the victims who recover from an electrical injury show any permanent disability.

THRESHOLD OF PERCEPTION

The threshold of perception was determined for direct current and commercial 60-cycle alternating current. Each subject sat in a relaxed position in a chair with the palms of the hands resting on two number 7 copper-wire electrodes. The hands were moistened with a salt (sodium chloride) water solution in order to reduce contact resistance and permit the use of low voltages for safety. The current was gradually increased so that the subjects might become acquainted with the faint sensations of warmth and tingling. Repeated tests were then made to determine the smallest current that could be felt. The average of several trials was taken as the threshold value. The 60-cycle threshold current for 115 men was: 1.1 milliamperes average, 0.4 milliamperes minimum, 4.0 milliamperes maximum. The results are in close agreement with the generally accepted value of one milliamperes.⁸ The threshold of perception for direct current for these 115 men was: 5.2 milliamperes average, 2.2 milliamperes minimum, 12.6 milliamperes maximum.

The tongue is probably the most sensitive organ likely to experience direct contact with a source of potential. In

fact, a popular method of testing dry cells is to touch the battery terminals to the tip of the tongue. It was therefore considered of interest to determine the minimum current that is perceptible. Each subject sat relaxed in a chair and held two platinum test electrodes lightly on the tip of his tongue. The electrodes consisted of two number 18 wires one inch long and spaced one-half inch apart by means of a Bakelite separator. Platinum wires were used to minimize galvanic effects. The threshold value varied over a wide range among the subjects tested, and there was considerable variation in repeated tests on the same subject. As before, the threshold was taken as the average of several trials. The 60-cycle threshold for 115 men was: 43 microamperes average, 4.0 microamperes minimum, 315 microamperes maximum. The threshold for direct current for the 115 men was: 44 microamperes average, 0.6 microamperes minimum, 783 microamperes maximum.

LET-GO CURRENTS

In these tests the subject grasped a test electrode consisting of a 12-inch length of number 6 copper wire. The circuit was completed by placing the other hand on a flat brass plate 8 inches in diameter. This permitted the subject to break the circuit at any time he desired, even though it was necessary for an observer to hold the hand flat to prevent it from curling (see figures 1 and 2). The current was gradually increased to accustom the subject to the sensations produced. After one or two trials, the current was increased at a moderate speed to a certain value, and at this point the subject was commanded to drop the test electrode. If he succeeded, the current was increased by steps until he was no longer able to let go of the wire; if he failed, the test was repeated at a lower value. The end-point was checked by several trials, insufficient in number to cause fatigue, but sufficient to permit an accuracy within a range of about 0.5 milliamperes.

Preliminary tests indicated that it was immaterial whether the other hand or one of the feet was placed on the indifferent electrode. They also indicated that the let-go current was unaffected by the surface condition of the hands, tests having been made with dry hands and hands moist from perspiration, salt, and weak acid water solutions. The standard procedure was to keep the subject's hand moistened with a weak salt solution during the tests. This was done in order to secure more uniform conditions, to lower contact resistances, and particularly to lessen unpleasant sensations at localized tender spots due to high current densities. As the salt solution dried on the hands, the voltage and resistance increased, although the let-go current remained substantially the same. It had previously been found by tests with open-circuit voltages from 5 to 9,720 volts that sensations and muscular reactions were proportional to the current and not the voltage. These two findings confirm the generally accepted opinion that current and not voltage is the proper criterion of shock intensity.⁸

Figures 1 and 2 show pictures of subjects near the limit of muscular control on 60 cycles. The let-go currents for 114 men were: 15.5 milliamperes average, 9.7 milliamperes minimum, 21.6 milliamperes maximum. As



Figure 2. The subject shown in figure 1 at about two milliamperes in excess of his 60-cycle let-go current

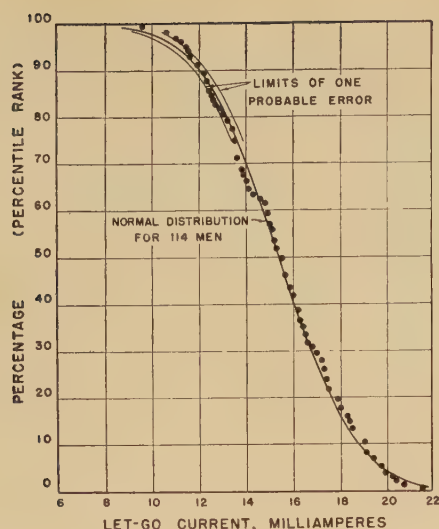


Figure 3. Distribution curve, 60-cycle let-go current

would be expected, the let-go current was higher for the huskier better-muscled subjects than for the thin, slight or lighter subjects. Right-handed men grasped the test electrode with the right hand, and left-handed individuals with the left. In the few trials that were made, the other or weaker hand had a limit of about 0.5 milliamperes less than the test hand in the same subject.

Let-go tests were also conducted with direct current. Steady direct currents produced a sensation of internal heating of the hands and arms with only slight muscular contraction, although severe muscular contractions were produced by sudden changes in current magnitudes, and a severe shock was experienced each time the circuit was broken. Many subjects stated they would almost rather maintain contact in spite of the burning sensation than experience the shock produced when they released the wire. The values obtained in the tests were the maximum currents released and represent the limit of endurance rather than the let-go value. The limits of endurance for 28 men were: 74 milliamperes average, 61 milliamperes minimum, 83 milliamperes maximum.

SAFE ELECTRIC CURRENT FOR MAN

Several factors must be considered in deciding what constitutes a safe current for man. The victim of an accidental shock can often release himself by using muscles little affected by the current. The muscular reactions pro-

duced by the current may tend to break the circuit rather than to improve it, or loss of balance may free the victim. However, it is doubtful if any of these methods would be of avail when contact is established by gripping an electrified wire so that the path of the current is across the body. Naturally, when a man realizes his dangerous predicament, he will exert more effort to free himself than that stimulated in these experiments. Fright, however, might tend to nullify his efforts, and exhaustion certainly would. It was therefore concluded that the safe electric current for man is that value which can be released by using muscles directly affected by the current.

The maximum current considered safe for man has been determined from a statistical study of the experimental results.¹² The curves of figure 3 show some of the results graphically. Obviously, the farther to the left one goes on the curve, the greater are the number of men who can release a given current. The conclusions are as follows: If it is assumed that the 114 men used in this experiment represent a cross section of all men of the same age and physical condition, then one man in 200 would not be able to let go of 8.8 ± 0.8 milliamperes or more current. This figure is based on a very conservative analysis. Having taken into consideration the factors mentioned, the authors are of the opinion that a reasonably safe 60-cycle alternating current for man is 8 to 9 milliamperes.

Steady direct currents produced much less severe muscular contractions than those produced by alternating currents. Within the range covered in these experiments, the physical endurance and will power of the subject fix the limit of the maximum release currents. Considering these factors, it appears conservative to conclude the maximum safe direct current for man to be at least 80 milliamperes.

For women and children the safe values for direct current and for 60-cycle alternating current may well be less, and in the interest of safety, no figures should be stated until adequate investigations have been made.

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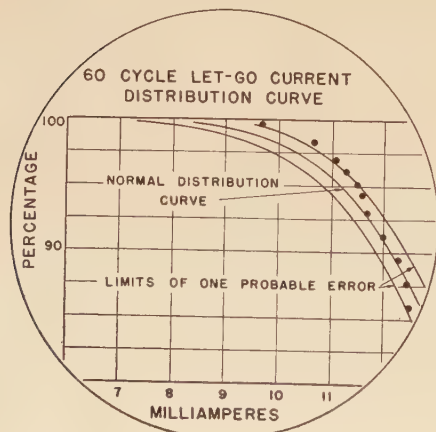


Figure 4. A magnified section of figure 3

Electric Utilities Under War Conditions

D. N. HEINEMAN

Some of the problems that beset utility operating and holding companies when war is in progress are described by an official of a European company with subsidiaries both inside and outside the war area; he also discusses the long-range planning which enable such companies to continue to function after the outbreak of war.

THE INDEX of electric consumption for a given country often is regarded as a barometer both of the business trend and of the standard of living. But figures of the total demand for electric energy in a particular area and period throw little light on the economic situation. In the past 50 years, electricity has become a consumption good of primary necessity and consequently a commodity the demand for which is singularly inelastic. Moreover, when buying of consumers' goods is restricted, the decline in the use of electricity for domestic purposes may be largely compensated by an increased demand for the output of producers' goods. This shift has taken place in a number of European countries during the past few years.

In preparation for the present war, means of production were drastically diverted toward the manufacture of armaments and the procurement of what were regarded as strategic commodities. Remembering the difficulties that resulted during the previous war from a lack of various raw materials and foodstuffs, Germany, Italy, and Hungary, to say nothing of Soviet Russia, embarked on four-year or five-year plans, all aiming at national self-sufficiency in staple goods. The execution of such plans implies regimentation of production and consumption, both of which may be profoundly modified in volume and nature. Such changes react of course on the electrical industry, but electricity supply may not be greatly affected, because the demand is likely to be shifted from one group of consumers to another. An increase in the total volume of business will, of course, bring about a higher electric consumption.

In the countries that contemplated isolation during the war, the acreage under wheat was increased by about 30



Courtesy British War Relief Society

per cent as a result of a series of "battles" led by their respective governments. At the same time efforts were made to promote the growing of vegetables and oil seeds, and to retain on the land, or to transplant from other areas, the labor required for augmenting production. In view of the enormous demand for men enrolled in military service a shortage of agricultural labor was inevitable; this was partly remedied by a wider resort to mechanization. Despite these endeavors the food problem seems to be solved only imperfectly in those countries, notably in regard to meat and dairy products, because of a marked deficiency of fodder and fertilizers formerly imported from overseas. In industry a higher degree of success has been achieved, and this implies a substantial addition to the normal demand for electric energy.

Take, for instance, Germany's war preparations. Ever since 1933 the economic system began to be directed toward a steady increase of the "*potentiel de guerre*"; yet a totalitarian economy was initiated only in the autumn of 1936, when the second four-year plan was announced at the Nuremberg party meeting. From 1935 to 1938 the output of iron and machinery rose by about 40 per cent, low-grade domestic ores being treated regardless of cost; the production of aluminum increased more than fourfold, exceeding that of the United States and Canada combined. The rise of about 53 per cent in electricity consumption is largely attributable to these developments. The manufacture of chemical substitutes for gasoline and lubricating oils has been furthered, again without regard to cost, and that of synthetic fibers probably will reach this year 300,000 tons. Rationalization has been ruthlessly pursued. Only the most efficient works were allowed to remain in

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operation. It is claimed that they are now working at 125 per cent of their theoretical capacity.

Similarly, in Italy iron and steel production largely has been centered in the mills of a single governmental holding corporation, which is producing at full capacity while its privately managed competitors are reduced to less than half their normal output, for lack of ore or scrap.

In both countries new approved investments have been encouraged by tax exemptions. In particular, the development of hydroelectric power stations has been furthered.

The anxiety to remedy a shortage of coal extended to private households and private commercial or industrial undertakings. An increase in the demand for electric heaters has been a feature in every country during the past few years; but in areas subjected to prewar or war conditions it was greatly accelerated. A sudden expansion in this demand might give rise to serious difficulties. For instance, it is estimated in Switzerland that the complete replacement of coal by electric energy for heating purposes would raise the annual consumption in that country from 7,200,000,000 to 24,000,000,000 kilowatt-hours. This danger has caused the authorities to limit both the purchase of electric household appliances and the private consumption of electricity.

In Germany, every form of demand for consumption-goods, including residential building, was—and is—restricted. Handicraftsmen and small retailers were driven into liquidation, partly with a view to increasing the labor force available to the armament industries or agriculture. The protection granted to labor under previous governments was withdrawn; hours were lengthened, women were pressed into service, and maximum wages were fixed without regard to variations in the cost of living. Choice of jobs was not only limited, but in many cases suppressed, workers being conscripted and allocated to the tasks for which they were most needed.

These conditions, together with a more and more developed system of rations and of prescribed uses for leisure, have altered the habits of the population in a manner that was bound to have repercussions on the consumption of electricity. The load-chart of the Berlin power stations shows a sudden and heavy drop at the times when the population gathers about the family radio or in the beer houses to listen to a speech from the Fuehrer.

Foreign trade also was affected by military preparations. Exports were furthered at the expense of home consumption, since it was urgent to procure raw materials that would be turned immediately into armaments or held in store for the outbreak of war. Imports were severely limited in the anxiety to husband foreign-exchange reserve. These foreign-trade policies have modified the economic situation in other countries, whose outlets were enlarged or diminished. In particular, political reasons or the attraction of barter facilities induced Germany and Italy to favor in their purchases the Balkan and South American countries to the detriment of Great Britain and the United States.

Germany's neighbors joined tardily in the armament race. Here also industrial output was increased under

the pressure of military requirements. But in France, progress was hampered by a lack of labor that was only partly corrected when the 40-hour week was abandoned, after Munich. The French Government deferred industrial mobilization until the outbreak of the war, and rationing was scheduled to come into force at the end of May 1940. Yet conspicuous developments materialized during the years preceding the war in the hydraulic power stations and high-voltage lines of France, thanks partly to private initiative and partly to governmental action. In the United Kingdom remarkable progress in the enlargement and rationalization of electric production was achieved through the institution of the "grid system."

In considering what European electrical undertakings have done with the specific intention of preparing for war conditions, it is necessary to distinguish between operating companies and holding corporations.

So far as I know, the operating companies have taken no precautions against the danger of invasion or bombardment, nor have the authorities ordered any particular measures, except that some hydroelectric stations were directed to empty their water reservoirs when an attack appeared imminent, for fear of the lower neighboring regions being flooded if the dam were destroyed.

A power station standing in danger of being cut off from its habitual sources of supplies would, of course, be well advised to increase its inventories of fuel, spares, and other materials or equipment, but I have not heard of any European electrical or gas works having done so to any notable extent. Many European power plants are established within easy reach of coal fields; they saw no point in stocking fuel. They overlooked the possibility of a stoppage in the coal output. The power stations in the Paris area, for instance, held only a three-day stock of coal, relying partly on shipments from England and partly on supplies from hydraulic plants with which they are interconnected. The 240,000-kw Truyère hydraulic power station in central France contributes to feed both Paris and Marseilles, and is interconnected with Swiss and Pyrenean works, thus forming the turning plate of the electric distribution in a wide area of western Europe. However, the network of interconnections established in Europe, though no doubt very helpful under war conditions in the Netherlands, Belgium, and France, is not at all tributary to any anticipation of war. These interconnections were intended to be works of peace.

In spite of the development of the grid system in England, some minor power stations still survive in the London area. Although uneconomic and condemned to disappear in due course, they constitute today, in abnormal circumstances, a valuable stand-by should the large modern works be put out of operation.

Quite different from the situation of the operating companies is that of holding corporations responsible for the maintenance and progress of a number of associated companies, operating outside of the war area. An operating company has enough to do attending to its daily work. If there is a holding company to mother it, the latter will worry about more remote contingencies and provide for them. A large holding corporation, as these are conceived

in Europe, carries on staff work for its associated companies, which implies much careful forethought when war is threatening and watchful guidance when war is on.

Let me cite as an instance Sofina, the Belgian holding and service corporation with which I am particularly acquainted. Its associated electric and gas utilities operate in a number of European countries, in Argentina and Mexico, as also in Northern Africa. In addition, it holds minor interests elsewhere, including the United States. The annual output of the associated companies totaled over 7,500,000 kilowatt-hours in 1939, and their installed power (water and steam) totals between 3,000,000 and 4,000,000 kw.

Long before the present war started, we tried to visualize what might happen if Belgium were invaded and it should become impossible to supervise and assist from Brussels the operating companies entrusted to our care. We decided that we would retire to positions prepared in advance.

It is the task of a holding corporation to keep its subsidiaries provided with technical guidance, supplies, and funds. The preparation of offices outside Brussels was one of our precautionary measures. In August 1939 we formed a company in the United States that would be in touch with our overseas undertakings and provide for shipments of supplies and remittances of funds in the event of its being impossible to execute these deliveries from Europe. Considering that supplies of coal from Wales or the European continent might be unable to reach our power stations in Portugal or in the Argentine, we started as early as December 1936 stocking large inventories of coal at these stations. When war broke out, they had a good ten months' supply; our Argentine stations held over 600,000 tons of fuel. Regardless of the comparatively high freight rates of American coal, we placed orders in the United States for shipments to the River Plate. Our advisory and purchasing staff in the United States has been considerably increased since the invasion of Belgium.

On May 10, 1940, Brussels was awakened at dawn by the whistling and banging of bombs, one of which fell not far from our head office. A selected staff of Sofina was ready to start immediately, by car or by rail, for Ypres, Belgium, where, months before, offices had been prepared. We were at liberty to displace our seat of administration, as a Belgian Act of February 2, 1940, had expressly provided that in the event of war any Belgian company would be permitted to transfer its seat to a new location, inside or outside the realm, by a simple decision of its board of directors, acting through any two of its members empowered to that effect.

However, we very soon were compelled to vacate our Ypres office. Because of the influx of refugees, the call to the colors of every Belgian lad between 16 and 19, and the reports of the German advance, Ypres became an awkward place for studying enlargements of electric plants and perusing our companies' accounts.

This time our ultimate goal was Lisbon, Portugal. We had chosen this distant haven, not because we expected the whole of France to fall under the sway of invaders, but because, we feared that rigorous French regulations might make it difficult in war time to communicate with our as-

sociated companies overseas as frequently as would be essential. Besides, Sofina is largely interested in the Lisbon gas and electric utilities. Offices had been in readiness there since June 1939, and duplicates of accounting records, engineering files, and contracts were kept there. Yet we contemplated an intermediary halt in France in order to collect our refugee employees. For a few weeks we camped at Biarritz, with a mere outpost in Lisbon.

Getting out of Belgium and proceeding through France was not an easy job. There were passport troubles, and the roads were choked by interminable caravans of cars pathetically roofed with mattresses as a safeguard against short-range machine-gun fire from the air. Train services had broken down; our Ypres staff was scattered; but by hook or by crook, by car, lorry, and bicycle, they managed to reach Biarritz, some experiencing thrilling escapes.

When it became manifest that the French army was about to surrender, some of our senior officers went to Madrid, where they discussed with the Spanish authorities questions pertaining to our interests in Spanish companies. There we met with a most friendly reception; but our goal was Lisbon, to which city we moved a substantial body of our staff. All those officers and employees of our company who had left Brussels—numbering close to 200 with their families—successfully negotiated the visa barriers which have retained so many people in France against their will. A certificate attesting that such and such a person belonged to the staff of Sofina had, at the various frontiers, the magic effect of "Open, sesame."

Portugal today enjoys prosperity under an orderly and far-sighted rule. This small country is the lung through which continental Europe still can draw a breath of air from those parts of the world where speech and trade retain a measure of freedom. At present, Lisbon is about the only place in Europe where Sofina can remain in easy communication with its associated companies.

Thanks to the staff work described, our undertakings operating outside the invaded areas have been able to carry on their business as usual. But they have been affected, of course, by the changes which war conditions brought about in production and trade throughout the world. For example, the nationalist outlook has been accentuated in almost every country, and currency difficulties have increased the restrictions put upon importation and exchange transactions.

In connection with the holding company's obligation to provide funds to its operating companies, no clear-cut dividing line can be drawn between money remittances and deliveries in kind. For example, our operating companies in Turkey had considerable sums of money to remit to Belgium in respect of dividends; but payments in cash to Belgium were limited by a clearing arrangement; so we found ourselves compelled to collect our earnings in the form of live sheep and wheat, eggs and hazel nuts.

In the countries engaged in war, external commerce and money remittances are severely regulated even in regard to occupied or allied areas. Every home production useful to the prosecution of the struggle has been speeded up, while domestic consumption has been further curtailed.

The changes in the purposes to which electricity is applied and in the volume of the demand for each class of purposes have become even more marked than during the period of war preparations. In the United Kingdom, as well as in Germany, industrial mobilization is in full swing and has not been checked to an important degree by military operations.

To my knowledge, physical damage to electric plants is relatively small. Power stations, high-voltage overhead lines, and substations have been bombed. Presumably there have been hits in a number of instances. However, destruction caused by bombing would appear to be less serious than might be expected. Thus the power stations in Spain in which Sofina is interested were repeatedly attacked during the recent civil war, but attacks inflicted only slight damage on the thermic power plants, and did negligible harm to the hydraulic works and their transmission lines. Sabotage caused greater havoc.

Again, we have found that economic activities are likely to pick up with remarkable resilience after the cessation of active hostilities. In Catalonia, for example, the consumption of electricity is again approximately what it was in 1935, the year before the outbreak of the Spanish civil war.

This recovery is due in some degree to the substitution of electricity for gas as a result of a scarcity of coal; yet it contrasts with the persistent depression from which Spain is suffering, and supports the view already expressed that electric distribution is conspicuous among the industries that enjoy an inelastic demand. Having become almost as much a necessity as daily bread, electricity is hardly sensitive to the effects of cyclic or even of quite abnormal variations in the business trend.

For the time being, in the territories that Germany invaded, as also in the so-called unoccupied part of France, the much diminished purchasing capacity of the population, destruction of industrial plants, and a general disruption of trade will probably be reflected in a marked decline of electric consumption. In Belgium, I gather, operation was interrupted in some power stations when fighting was going on in the immediate vicinity. On the other hand, factories were obliged to close down when the Army mustered all its forces. Moreover, in a number of instances, steel works, cotton mills, collieries, and other undertakings of strategic importance voluntarily dismantled sections of their machinery in order to prevent operation under enemy control.

However, I hear that electric distribution has been resumed practically throughout the country. The bills go out to the customers as before, reduced in amount rather than in number. Sooner or later, electric distribution must assist in healing the wounds that war has inflicted, and the electrical industry should be one of the first to benefit from the recovery it will have helped to bring about.

Let us assume, as we confidently anticipate, that the world of tomorrow will not come under the sway of totalitarian regimentation, but rather will benefit from the lessons of this dreadful ordeal, and be free to shape a better order for mankind. Under war conditions an exceptional degree of government interference in private enterprise

and private households is necessary, and consequently acceptable. We trust there will be a healthy reaction against the spread of state management as soon as this regimentation will have survived its usefulness. The preparation and prosecution of the present war have taught how production can be furthered and unemployment reduced, almost beyond belief, when the will of a nation is set in increasing the output of goods and services. We have also learned to what extent the available wealth can be increased by husbanding resources. A common ambition and a common fear have diminished the disintegrating forces of class hatred. This war has shown the constant need of planning well ahead, the strength of teamwork, the weakness of slipshod dispersion of efforts. It is likely to demonstrate the futility of attempts at national self-sufficiency.

We must guard against the danger that may rise from the spirit of national isolation, which is naturally fostered in years of strife and threatens permanently to set up new barriers in the way of international relations.

The works of the electrical industry are of peace; its task is public service. Utility men have a role to play in the preparation of peace for the day when the armed forces of evil shall be overcome. On a modest scale, utility companies with widespread interests are called upon to study and practice international co-operation, in tranquil as well as in troubled times. They learn acutely to realize the interdependence of nations.

It is absurd to believe that a community can fare better through restricting its choice of commodities or limiting the field within which it can render service. The world at large—mankind of today and generations to come—and each group of human beings in particular are the poorer for every obstacle put in the way of trade and friendly intercourse, for every ostracism decreed against men of a given religion or race.

The legitimate dread of "fifth columns" may cause responsible statesmen to look askance even at inscriptions in the columns of a business ledger. But international investments of capital, and the technical experience that usually is applied to the management of these investments, are equally beneficial to the country that invites or accepts foreign enterprises and to the country that enjoys this form of hospitality.

A large number and variety of international conferences sought to further the spread of knowledge. War has suspended these meetings. Censorships and enactments purporting to prohibit the reception of foreign broadcasts are curtailing the scope of mutual information. The world's distributing system of physical and spiritual wealth is pitifully disrupted, in a period when the means of exchanging goods and ideas are more highly developed than ever heretofore.

Humanity can never thrive in an air saturated with the poison gas that has spread over the greater part of Europe. The western European nations were unable to resist brute force; they enjoyed freedom but they lacked the spirit of collaboration. They were not prepared to face with an undivided will the onslaught of co-ordinated means of action applied by their enemies. Their weakness and its

causes afford a fearful lesson to all nations not enslaved.

The substratum of every conscious co-operation is mutual good-will. But good-will alone will not suffice. There must be agreement on some essential principles of political and economic government.

Let us recall the conditions under which an electric utility can best contribute to the public welfare: orderly liberty in initiative and association, helpful discussion for mutual understanding, the prudent building up of reserves against an hour of need, and a fair reward for reciprocal service. The same conditions would apply to every field of human activities. If widely and wisely ensured, I am confident that, figuratively speaking, their establishment would electrify the world.

Stevens Point—Minneapolis Coaxial Cable

THE first commercial installation of coaxial cable in the Bell System now is being completed between Stevens Point, Wis., and Minneapolis, Minn., a distance of approximately 200 miles. As may be seen from the accompanying illustrations, the cable contains four coaxial units in the center and an outer layer of 18 19-gauge quads. In the central space formed by the coaxial units are two 22-gauge pairs, and in each interstice between coaxial units is a hybrid quad made up of one pair of 19-gauge and one pair of 22-gauge wires; these are required for auxiliary service. The experimental cable installed several years ago between New York, N. Y., and Philadelphia, Pa. (*EE Jan. '37, p. 4-7*) contained two coaxial units and four pairs of 19-gauge wires.

The coaxial units of the new cable represent an improvement over those of the New York-Philadelphia cable. In the latter, the outer conductor consisted of a number of separate interlocking tapes; in the new cable, the outer conductor consists of a single tape which is formed into cylinder as it is pulled through a die, proper registry of the edges along the seam being obtained by the provision of projections or "teeth" along each edge of the tape. The tube so formed is held together firmly by a serving of steel tapes.

Before the details of design were decided upon, preliminary experimental cables with different modifications of construction were manufactured and thoroughly tested. In this preliminary work, it was found that a cable could be designed and manufactured with the necessary factor of safety to withstand at least as severe handling as is normally required in the factory and in the field.

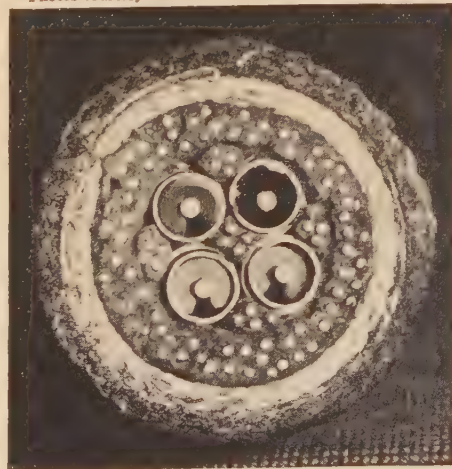
In addition, the experimental structures also were tested for their electrical characteristics. The effective resistance and inductance were determined at

frequencies up to 5,000 kilocycles to check calculated values. The dielectric constant of the composite coaxial unit was found from the test of capacitance and the known dimensions of the conductors to be about 1.1 at 5,000 kilocycles. Particular emphasis was placed on the test for conductance loss of the rubber disks. The increase in conductance with frequency and its change with temperature were determined over the range from 60 to 5,000 kilocycles. Test data showed that at 70 degrees Fahrenheit conductance increases approximately as the 1.08 power of frequency up to about 1,000 kilocycles, and as about the 1.02 power from 1,000 to 5,000 kilocycles. The dielectric strength became the subject of a somewhat extended investigation, and it was found that by careful removal of foreign material and projections from the surfaces of the center wire and copper tape, and thorough cleaning of the rubber disks, the dielectric strength could be improved sufficiently to permit a guarantee that the structure would withstand a d-c potential of 2,500 volts.

Concurrently with the evolution of the design of the coaxial conductor, transmission studies were clarifying the requirements a conductor should meet as a transmission medium. An extraordinarily high degree of impedance uniformity as compared with other types of circuits was found to be important. Since impedance uniformity depends upon mechanical and physical uniformity of the coaxial unit, great care was taken in its design and in the design and operating characteristics of the manufacturing equipment to assure a highly uniform product. In addition, special care was required in drawing the wire used for the inner conductor, and in rolling the tape for the outer conductor, in order to achieve the required high degree of mechanical uniformity.

Structure and cross section of Stevens Point—Minneapolis coaxial cable. Overall diameter is 1.7 inches; inside diameter of the coaxial unit is 0.27 inch.

Photos courtesy "Bell Laboratories Record"



Sun-Spot Disturbances of Terrestrial Magnetism

W. F. DAVIDSON

FELLOW AIEE

ALTHOUGH communication engineers have long recognized the existence of magnetic storms or disturbances in the normal magnetic field of the earth, power engineers generally have not been aware of the fact that the storms could reach sufficient magnitude to cause operating disturbances in electric-power systems. Consequently, when on March 24, 1940, a number of power systems in the United States and Canada experienced operating difficulties coincident with the onset of a magnetic storm, the subject received widespread comment. The present discussion is a brief summary of power-system experience with some notes on the general subject of magnetic storms and the theories that have been advanced to explain them. For the latter, the author is indebted to Doctor A. G. McNish of the department of terrestrial magnetism, Carnegie Institution of Washington and particularly to the material he prepared for presentation before a recent meeting of the engineering committees of the Edison Electric Institute.¹ The information on power systems was obtained chiefly through responses to letters sent out by the Edison Electric Institute.² Valuable information on the effects of the storm on communication systems have been supplied by L. W. Germaine, long lines department, American Telephone and Telegraph Company.³

Power systems reporting disturbances are located in New England, New York, eastern Pennsylvania, southern and eastern parts of Minnesota, Ontario, and Quebec. On the ten systems on which disturbances were noted, the effects listed in the inverse order of the number of cases reported were:

1. Voltage dips ranging up to ten per cent, but generally of short duration (seven cases).
2. Tripping transformer banks by differential relay operation (five cases involving 15 transformer banks).
3. Large increases or swings in reactive kilovolt-amperes (four cases).

In addition, we have three separate observations:

1. Direct current was measured in a neutral grounding (one case).
2. Distortion of the current wave in a neutral grounding connection was recorded by oscillograph (one case).

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Essential substance of a paper presented informally at the AIEE Middle Eastern District meeting, Cincinnati, Ohio, October 9-11, 1940.

1. For numbered references see list at end of article.

For many years magnetic storms at irregular intervals have been known to interfere seriously with the operation of electrical communication systems. The storm of March 24, 1940, however, considered to be possibly the greatest magnetic storm that has ever been recorded, not only interfered widely with communication systems, but also caused numerous interruptions in electric-power systems. The latter experiences are reviewed here, followed by some notes on current theories concerning magnetic storms.

3. A few blown transformer fuses on a 2,400/4,150-volt radial distribution system (one case).

No serious operating difficulties or interference with service were reported, possibly because it was Easter Sunday and loads were unusually light.

The instances of transformer tripping are probably of first importance because they present the largest potential possibility of interference

with service. Examples are (eastern standard time throughout):

Two 75,000-kva transformer banks on the 220-kv system of the Philadelphia Electric Company—Public Service Corporation of New Jersey—Pennsylvania Power and Light Company, eastern Pennsylvania and New Jersey, tripped out by differential relay operation at 11:48 a.m. At about the same time, there were voltage swings of about 1½ per cent and reactive power surges of about 20 per cent.

On the 220-kv system of the Niagara District, Ontario Hydro-Electric Commission, four transformer banks were tripped out by differential relay operation at 11:48 a.m.

On the 132-kv Abitibi system of the Ontario Hydro-Electric Commission, six transformer banks tripped out by differential relay operation at 11:48 a.m.

The 40,000-kva transformer bank connecting the 11-kv and 110-kv systems of the Narragansett Electric Company in Providence, R. I., were tripped out by differential relay operation. Shortly after this, an ammeter was connected in the transformer neutral and a direct current of 25 amperes was recorded. At the time of this observation, no operating difficulties were being experienced.

Two transformer banks operating from the 110-kv lines of the Central Maine Power Company at Bucksport were tripped out by differential relay operation at about 11:15 a.m. with accompanying voltage dips as large as eight per cent.

Some mention already has been made of reactive power surges and voltage dips. Other cases where these phenomena were observed, but without causing equipment outage, include the following:

On the system of the Northern States Power Company centering about Minneapolis, Minn., there was 105,000 kw of steam generating capacity in service in stations in the Minneapolis area and another 10,000 kw at Minnesota Valley, roughly 100 miles to the west. Two 10,000-kva synchronous condensers were operating in the Minneapolis area and one 5,000-kva synchronous condenser at Mankato about 100 circuit miles to the southwest. Transmission circuits involved were principally 69 kv with transformer banks generally wye-delta with grounded neutrals on the 69-kv side. In addition there are a few autotransformers connecting to the 115-kv system, these having delta-connected auxiliary windings. With few exceptions single transformers are used. The first disturbance in the nature of a surge as indicated by shift of load on the synchronous

condensers was observed at about 10:45 a.m. This was followed by numerous other surges at irregular intervals until 1:45 p.m. There was a slight recurrence of minor severity between 10:30 and 12:15 p.m. The most severe of the surges occurred at about 11:50 a.m. when the total build-up and decay period seemed to cover about four minutes. During that time the synchronous condensers which were operating on voltage regulators shifted load from maximum buck to maximum boost and return. There was an accompanying drop in voltage of about ten per cent. Considerable surges in reactive component on several of the circuits such as the Wisconsin-Oak Park 115-kv line where a change of 10,000 reactive kva was recorded. The graphic wattmeters showed no corresponding indication of the disturbances, and there were no circuit breaker operations. At Sparta, Minn., approximately 150 miles to the southeast of Minneapolis, the 69-kv line-regulation transformer operated to the extreme position in each direction and a lightning arrester discharge was noted.

On the Newburyport-Haverhill 22-kv double-circuit line of the Eastern Massachusetts Electric Company, the current was in the order of eight amperes, or about the charging current of the line, until late in the morning when the disturbances began. At that time swings to as high as 60 amperes or somewhat more than normal full-load current, were observed. Individual swings had a duration of a minute or less but recurred at frequent intervals over a period of some 10 or 15 minutes. There was considerable accompanying voltage drop.

On the Consolidated Edison 60-cycle system in New York, N. Y., a series of voltage disturbances took place beginning about 11:48 a.m. The first dip, which varied from $1\frac{1}{2}$ per cent to 10 per cent in different parts of the system, was followed by a series of minor dips continuing at short intervals for a period of about one hour. The 25-cycle system voltage was not affected nor was there any appreciable change in system frequency or change in load in any part of either system. The voltage dips were of lower magnitude than those often caused by high-voltage feeder faults and did not have any serious effect on operation of customers' equipment or on the operation of the system. An analysis of available data indicates that on the 60-cycle system, the increase in reactive load was in the order of 45,500 reactive kva.

On the 110-kv system of the Niagara Hudson Power Corporation, there were numerous operations of an automatic oscillograph installed at Lockport, N. Y. A study of some of the records show that the neutral current has the characteristic wave form obtained with transformer operating with direct current superimposed on the alternating-current excitation, but since the oscillograph was operated through a current transformer, there was no direct observation of direct current.

The Boston Edison Company reported a considerable number of blown transformer fuses on its 2,400/4,150-volt radial distribution system. All were on transformers at the ends of feeders at points where the neutral was continued past open tie switches to feeders in adjacent areas.

For the purpose of explaining what happened in the power systems, I shall refer chiefly to the New York system, for which an extensive analysis has been made. It was noted that:

1. There had been voltage dips of short duration and considerable magnitude.
2. There had been increases in reactive kilovolt-amperes coincident with the voltage dips and proportionate to them.
3. There had been no appreciable change in the power components, that is, in kilowatt load.

These phenomena were, at least qualitatively, what would be expected if direct currents flowed in the windings of transformers so as to cause saturation and lead to increased a-c magnetizing currents.

H. B. Seeley of Consolidated Edison Company, has

made a number of calculations in which he has used test data showing the effect of superimposed direct currents on transformer characteristics and has made the assumption of an earth-potential gradient of 10 volts per mile. He also used in his calculations the known electrical characteristics of typical feeders on the radial distribution system. The result is a calculated increase of 26.4 reactive megavolt-amperes compared with an observed 25—a convincing argument as to the validity of explanation.

With this analysis in mind, we can explore some of the other cases, for example, the interconnected 69-115-kv system of the Northern States Power Company. The test data previously mentioned would lead one to expect that each ampere of direct current in the 69-kv windings of single-phase transformers would cause 75 reactive kva increase, and each ampere in 115-kv windings would cause 125 reactive kva increase in excitation. Assuming an average of these two values, it follows that only about 0.75 ampere of direct current in the neutral for each 1,000 kva of transformer capacity would be necessary to explain the observed increase of 30 reactive megavolt-amperes on about 400 megavolt-amperes of transformer capacity.

The disturbances in which transformer banks tripped on differential relay operation require no extended analysis. If direct current flows in one winding, it will not induce a corresponding current in the other, and in consequence single-phase transformers will have a steady magnetic flux in one direction which in turn will lead to saturation and increase the magnetizing component. The magnitude of this unbalanced component has been indicated in the previous discussion; for a 220-kv transformer one ampere of direct current will cause an increase of about 200 reactive kva in the magnetizing component, which appears as an unbalance at the differential relays. Coupled with this there will be a distortion of the wave form as indicated by the oscillograph. Insufficient data are available to permit making a statement as to the effect of this distortion on relay performance, but it seems probable that the effects will be generally in the direction of increasing the apparent sensitivity, thus further decreasing the amount of actual unbalance necessary to cause relay tripping.

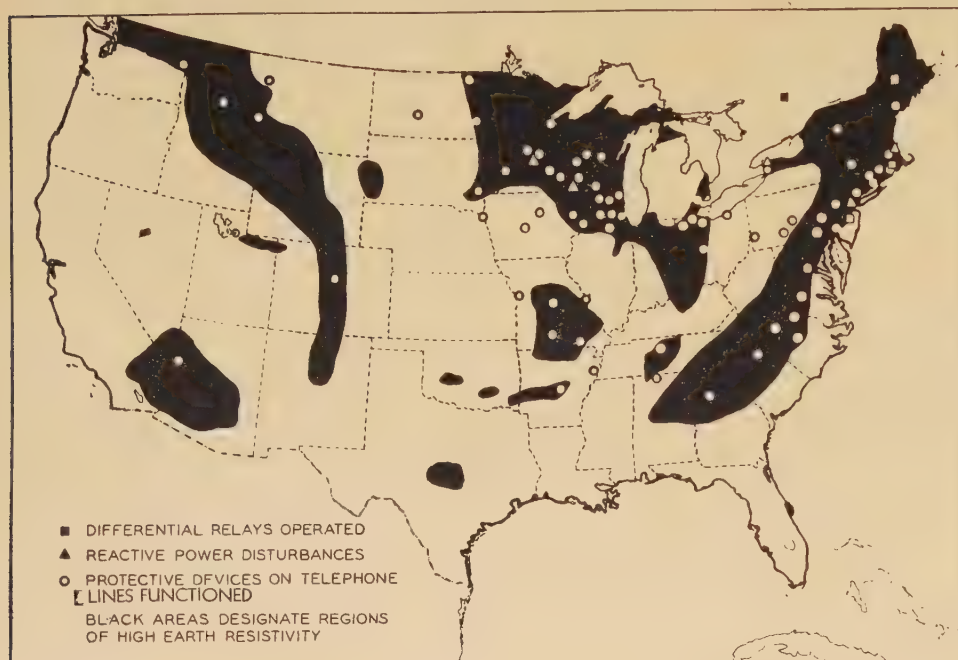
Some thought has been given to the effects of direct currents on the ratio and phase angle of instrument transformers, but all of the test data so far examined suggest that the effects are of secondary importance. Instrument transformers generally operate at comparatively low magnetic flux densities, and in consequence they are far less susceptible than power transformers to the disturbing effects of superimposed direct currents. Relatively large d-c components are necessary to make a five per cent change in ratio of current transformers or to cause a similar error in the ratio of potential transformers.

In seeking further light on the underlying phenomena involved in the magnetic storm, we may next turn to the data collected by the Bell Telephone system. Like the telegraph companies, telephone companies have long been aware of magnetic storms and have taken steps to place

instruments so that records of their currents could be observed. Many recording voltmeters are in continuous operation connected between ground points at various central offices. From an analysis of their records, it is known that potential differences of 400 volts or more occurred between numerous line terminals. One of the most serious effects of these disturbing voltages was the operation of the protective devices installed in central offices at the juncture of open-wire and cable plant. In numerous cases, the voltages continued at such high values that the protective devices operated as fast as they were closed, making it impossible to use the circuits.

April 1938, energy was expended at the rate of 2,000,000 kw for a two-hour interval. The storm of two years later appears to have been even more intense so it is not surprising that there were effects even on power systems of 2,000,000 kw connected capacity.

To quote now from Doctor McNish:¹ "Mathematical analysis has shown that field changes during magnetic storms are due principally to causes above the earth's surface, presumably electric currents, and that these external effects are accompanied by effects due to the induction of currents within the earth by the primary external fields. It is an unfortunate limitation of mathematical



Observed disturbances on communication and power lines in United States and southern Canada caused by magnetic storm of March 24, 1940

In other cases, intermediate discharges across the gap of the protective devices were so frequent and severe as to make the circuits noisy and not satisfactory for service.

Analysis of the data obtained during this particular storm confirms earlier observations which show that the largest potential gradients occurred in areas known to have high earth resistivity. It may be observed that these areas are the same ones in which power-system disturbances were noted.

Coming now to the matter of a more fundamental explanation of the nature of the magnetic storms, we find that we enter a field of speculation in spite of the enormous mass of exact scientific data that has been accumulated during the past century or more. For many years, magnetic observatories distributed throughout the world have been accumulating information on the earth's magnetic field. From these it is known that there are continual changes not only from day to day but from hour to hour; usually these changes are so small as to produce no noticeable effect even in communication circuits with earth return. However, during the periods of magnetic storm, the changes become very much greater. Some idea of their magnitude may be gained from Doctor McNish's calculation that during the great magnetic storm of

analysis that it cannot describe uniquely both the location and configurations of these external currents, although with the assistance of mathematical analysis and some other considerations one may deduce probable locations and configurations. The field changes may be divided into two classes—those which are symmetric about the earth's magnetic axis and those which are non-symmetric. The first class may be thought of as due mainly to a large ring current about the earth, like the rings of Saturn, or to a current flowing in the outer atmosphere with intensity varying as the cosine of the geomagnetic latitude from zero at the geomagnetic poles to a maximum at the equator. The inferences we may draw from magnetic observations are entirely ambiguous in this regard for they permit either possibility. If the ring current is the correct conception its radius may be several times that of the earth. During the first phase of a magnetic storm the current in this ring flows from west to east and during the main or second phase it flows from east to west; the magnitude of the current reaches several million amperes at its maximum during great magnetic storms. Although the greater part of the energy of magnetic storms is involved in this hypothetical ring current, the magnetic changes are not rapid enough to

induce the very high potentials within the earth which play havoc with electric systems.

"The second class of field changes, which are nonsymmetrical about the earth's geomagnetic axis, are associated with electric currents flowing with maximum intensity along the auroral zone. There is every assurance that these currents are confined to our atmosphere, probably at a height of about 100 kilometers or so, where radio observations and auroral phenomena attest that the atmosphere is highly ionized. Field changes arising from these currents are responsible for the effects on communication and power lines.

"Observation of the field changes at a number of stations during various magnetic storms has permitted mapping of typical current-circulations. In general, these consist of intense currents flowing in an east-west direction along the auroral zone with diffuse return circulations—also confined to the atmosphere—across the polar cap and in low latitudes. Westward currents predominate on the morning side of the earth and eastward currents on the afternoon side, the westward currents being in general more intense. Such currents may continue for an hour or several hours but rapid changes in their intensity take place. Obviously, with such a distribution of currents, although a magnetic storm may be occurring all over the earth, certain places will be subject to more intense disturbance depending upon the location of the place and the time of day at which the magnetic storm began. The strength of these auroral-zone currents may

exceed 1,000,000 amperes and changes exceeding 100,000 amperes in one minute have been observed. Although the path may be 100 miles or so in width, to a first approximation it may be regarded as confined to a vast trolley-wire stretching for hundreds of miles in an east-west direction at a height of about 100 miles above the earth.

"The cause of the primary electric currents in the outer atmosphere or about the earth remains a matter of speculation. We know definitely that solar activity is directly responsible for magnetic storms—magnetic storms vary in frequency with the sun-spot cycle and exhibit a quasi-periodic effect which is associated with the sun's rotation."

Finally, a word as to "what to do about it." The record of past years indicates that while there will be recurrence of magnetic storms of great magnitude, their effects probably will be no greater than just described. What the effects on service might be is for others to say. Possibly they are serious enough to justify a review of differential relaying to determine whether changes can be made that will reduce the sensitivity as steady d-c components in the neutral increase.

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Developments in Resistance Welding

R. T. GILLETTE

A survey of the recent developments that have given resistance welding its present importance in high-speed industrial production

IT IS well known that the first resistance welder was conceived and built by Doctor Elihu Thompson early in 1886. While this welder was crude and of low capacity, it demonstrated that the basic principles of resistance welding were sound and of great value to the fabricating industry. Although the first welder was a butt welder, the other types of resistance welding—spot, projection, seam, butt-flash, percussion, and modifications of each—were soon developed from information obtained from the early work done on the first few machines.

The early resistance-welding machines were mostly manually operated and timed and were capable of making

only a few welds a minute. A machine rated at 25 kva was considered quite a large machine.

With the development of high-speed production methods in the automotive industry, followed by the same methods in many other industries, resistance welding rapidly attained a major position in many types of metal fabrication. Welding machines were constantly improved until at present they compare favorably with the best type of machine tools. The electrical capacity also has increased rapidly, so that resistance welders of 200 kva to 500 kva are very common and welders with capacities as high as 5,000 kva have been built and are in operation.

A brief description of some of the more recent developments might be of interest. To avoid confusion, it will be advantageous to treat the developments separately.

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1. For all numbered references see list at end of article.

CONTROLS

The control of time of current application on the early resistance welders was very inadequate, but with low-capacity welders working mostly on low-carbon steel acceptable results were obtained. Most of the earliest controls were simple pass-through switches operated by the foot pedal of the welder, which closed the switch as pressure was applied to the part to be welded. A further movement of the foot pedal opened the switch. By this method the operator controlled the time of current flow. Obviously the timing was very erratic. This type of control with some modification was used on all types of welders. As motor or other mechanical drive was applied to welding machines, cam-actuated limit switches operating solenoid contactors became the common method of current control. These were an improvement over the straight manual control but still had several deficiencies. The gap in the contactor changed rapidly, due to main contacts wearing. Maintenance costs were high and the switching was nonsynchronous.

At about the same time, seam welders were equipped with mechanical interrupters of various types. In some cases these interrupters were driven with synchronous motors in an attempt to get interrupters to operate without flashing. These devices, however, were difficult to keep in operation because of wear of parts and change of power factor on the welding machines, and about 300 interruptions per minute was the maximum speed at which

they could be operated. At this time the electronic control with its fully synchronous switching was developed. Figure 1 shows a combination control used for spot, projection, pulsation, and seam welding. At about the same time many steel alloys, including the stainless steels, were being developed and put into production. Also, the use of resistance welding for fabricating the nonferrous metals and alloys was growing rapidly. Very short welding times are required for fabricating these metals and the electronic control was particularly adapted to this work.

It is also well known that the current applied to a welding transformer at a point on the wave earlier than the power-factor angle will cause a transient condition that may give several times the normal current for a short time. This transient condition soon was discovered to be more serious than a small variation of time, as is indicated by oscillograms showing synchronous and nonsynchronous switching (figure 2). One of these transients may actually burn a hole through the work piece.

The use of these fully synchronous electronic controls gives an accuracy in control never obtained with any of the mechanical devices. They are particularly adapted for use as seam-welding interrupters due to their accuracy in always switching on the proper point of the wave to eliminate transients, and the speed can be anything up to 1,800 per minute, or one cycle on and one cycle off on 60-cycle current. They may also be used as current or heat regulators by firing at various points on the voltage wave, thus using only part of each half-cycle. This is shown by the oscillograms in figure 3. This method may be used alone or to supplement the standard tapped transformer.

Electronic control is available in all sorts of combinations for any type of resistance-welder control.

Supplemental to the development of the fully synchronous completely electronic control, many other types of

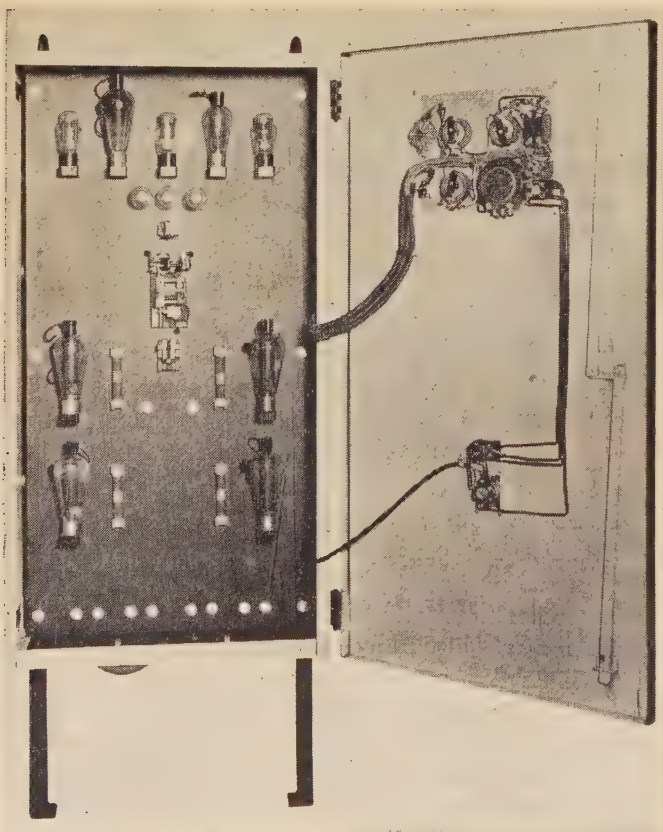


Figure 1. Front view, with door open, of enclosed Thyatron control panel for spot, pulsation, and seam welding, 220, 440, or 550 volts, 60 cycles

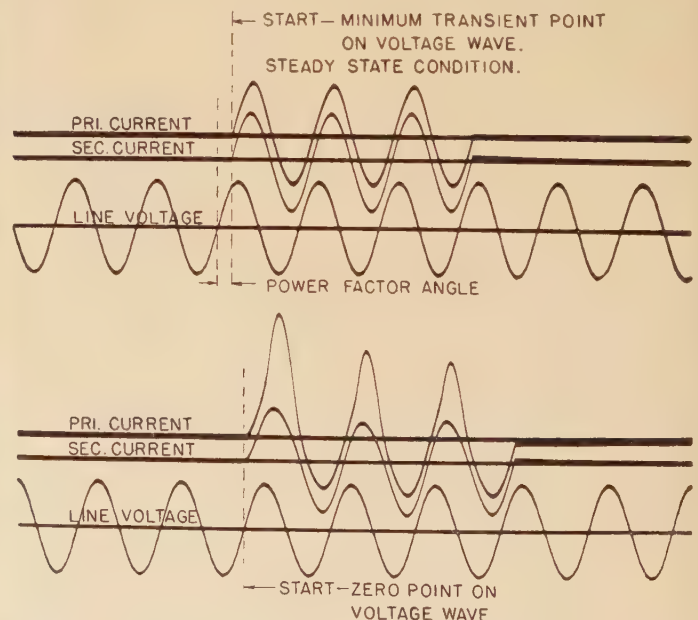


Figure 2. Oscillogram of line voltage and currents in welder transformer, showing results of starting current flow at different points on the voltage wave

control have been developed—some partly electronic and partly mechanical and others entirely mechanical—for use on motor-driven welders, as well as sequencing controls for air-operated welders which sequence and time the lowering of electrode, time of current dwell, squeeze time, and raising of electrode. These various types of control are cheaper than the complete electronic control, which perhaps is their chief recommendation. However, they do fill a need for a relatively cheap control where the ultimate in speed and quality of product is not the principal consideration. All the recently developed controls are much better than those used only a few years ago.

The development of accuracy in controls, and the use of very short times in welding, have radically affected the design of welding machines. The movable parts must be built as light as possible to reduce inertia to a minimum, so that the electrodes will follow and push up the weld and not lose contact and cause arcing in the weld area. Friction in the welding machine should be kept as low as possible for the same reason.

The electrical capacity in many of the new types of welding machines is higher than that of the older machines in order to deliver enough energy in the very short welding times now used. Many welds are now made in from 1/2 to 3 cycles on 60-cycle power, while many of the old machines used more than as many seconds.

POWER SUPPLY

Considerable work has been done to develop ample power supply with low voltage drop to supply the single-phase high-current intermittent power used on the larger sizes of welders.¹ The use of series capacitors for power-factor correction is also a recent development.²

PROTECTIVE DEVICES

The usual procedure on resistance welders is to ground one side of the secondary circuit, but this is not possible in some special machines. In such cases the secondary circuit is grounded through a modified Thyrite lightning arrester which grounds at approximately 50 volts.

A good type of air circuit breaker is also used in many cases to protect welding machine and line from short circuits and overload.³

MEASURING INSTRUMENTS

It is many times of great value to be able to measure as a permanent record the current used to make a weld, or to be able to duplicate a certain welding setup in some other place than the one in which it was first used. An oscillograph of course can be used but requires considerable time and skill and also is expensive when used in production. A newly developed instrument called a stop-pointer ammeter is of considerable value for this work.⁴

A somewhat different method of measuring welding current has been described by Hess, Wyant, and Muller.⁵

A cycle recorder has also been developed to record the actual number of cycles used in a weld. This is of value for checking timing of welds, making records for inspection purposes, and for other uses.

A weld recorder is available that records amperes-

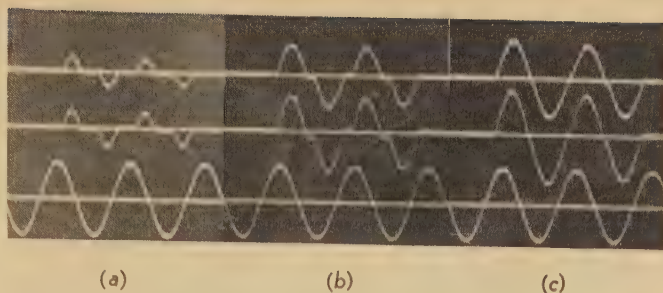


Figure 3. Oscillograms of current in welder, using phase-shift method of heat control by means of Thyatron welding controls. The top curves show primary current; the middle curves secondary current; the bottom curves line voltage

- (a)—Minimum heat (approximately 8 per cent)
- (b)—Moderate heat (approximately 55 per cent)
- (c)—Maximum heat (100 per cent)

squared seconds. Where very high quality is required, this instrument records the conditions of current. During the weld time it is sensitive to line voltage, variation in timing, and any other factors, such as condition of material and electrode maintenance, that affect time or current.

SPOT WELDING

Spot-welding equipment has been developed rapidly in the last few years along several lines. Although the press-type welder making one spot at a time is still standard, where many spot welds are to be made on rather large complicated assemblies, several types of hydraulically operated multiple-electrode machines have been developed.

One outstanding type uses a frame designed to act as an assembly fixture, with each electrode mounted on its individual hydraulic cylinder. The assembly to be welded is mounted in the machine; then all the electrodes are brought into their pressure position and act to clamp the work. Each electrode is electrically connected to a common transformer, through a straight-line commutating device, combined with an electronic timer; the current is turned off while the brush is traveling from one commutator segment to the next; and an auxiliary contact energizes the electronic timer for a definite time. In this manner, spot welds are made in rapid succession with all electrodes under pressure. These welders have great flexibility of operation and can be built for many types of structures. The fact that all electrodes are held under pressure while the welds are being made tends to reduce distortion to a minimum. Machines of this type have been built with more than 100 welding stations.

For spot-welding aluminum and its various alloys, two types of equipment have been developed. One type, developed by Sciaky of France, has found quite wide application in the United States. It uses stored magnetic energy in the welding transformer. This energy when collapsed gives a high secondary-current impulse of short duration with a steep wave front. Some machines of this type also use a variable pressure cycle during the welding time. Starting with high pressure, the pressure is reduced while current is flowing, then increased again to give extra

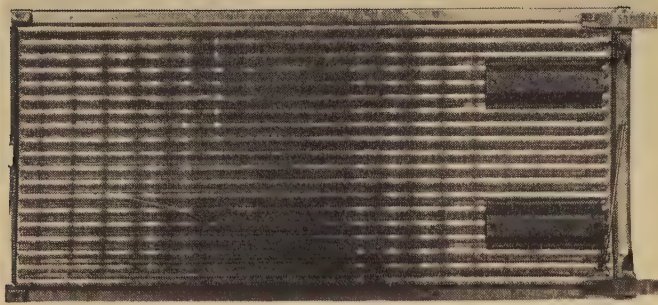


Figure 4. Condenser for one type of refrigerating machine, fabricated by resistance welding

forging action at the end of current flow. This type of equipment seems to be finding considerable use in aircraft factories.

The American-made counterpart of this machine stores the energy electrically in a bank of capacitors. These capacitors are charged through a three-phase rectifier, then discharged through the primary of a special transformer which again gives a unidirectional current with a very steep wave front. This machine may or may not use the variable pressure cycle.

The results from these two methods of welding aluminum alloys seem to be quite comparable.

PULSATION WELDING

Pulsation welding,⁶ in which the current is supplied in several increments rather than continuously, has been improved in its application to spot welding. Applying the current intermittently allows water-cooled electrodes to dissipate their heat during the off-current time, giving longer electrode life. It also allows better heat distribution when spot-welding heavy material. This method has been used for welding material of thickness ranging up to that of two pieces of one-inch steel.

Details of the pulsation method of welding were published in a serial article by H. C. Cogan and Ralph S. Pelton in the *Welding Journal*.⁷ The use of fully synchronous electronic control is essential for the satisfactory application of pulsation welding.

PROJECTION WELDING

A modification of spot welding in which the current is localized by projections on the work pieces, instead of electrodes with a reduced section end, is finding increasing applications. This method permits using electrodes of large section faced with the new hard electrode materials, giving lower maintenance costs and better quality work. It also allows making multiple welds in one operation on condensed sections where spot welding cannot be conveniently used and simplifies the problem of jigs and fixtures, thus lowering fabricating costs.

SEAM WELDING

The development of fully synchronous electronic control has made possible many outstanding developments in seam-welding equipment. A typical example is the seam

welding of a refrigerator condenser (figure 4). These condensers have 900 inches of weld and first were welded on the old standard seam welders (figure 5), which produced an average of $3\frac{1}{2}$ condensers per hour.

After several steps of development, a very successful ten-wheel seam welder was produced. This machine has five transformers, each rated 200 kva, with two welding wheels to each transformer, on top of the work, and a special copper-alloy shunting platen below the work, making two seam welds in series. It is equipped with five fully synchronous electronic control panels, including phase control for heat regulation. The continuous rms load on this welder is approximately 1,050 kva and its production is from 60 to 65 condensers per hour. At an estimate of 60 per hour, it makes over seven miles of seam weld every eight hours, or, considered as single overlapping spot welds, 4,320,000 spot welds every eight hours.

Where long rows of equally spaced spot welds are made, it is frequently possible to make them on seam welders. For one such application, requiring several hundred spot welds per assembly, a seam welder with two transformers and four welding wheels (figure 6) is used with the electronic control set with the off-time long enough to make 7 welds in two inches instead of a continuous seam. This welder makes spot welds at the rate

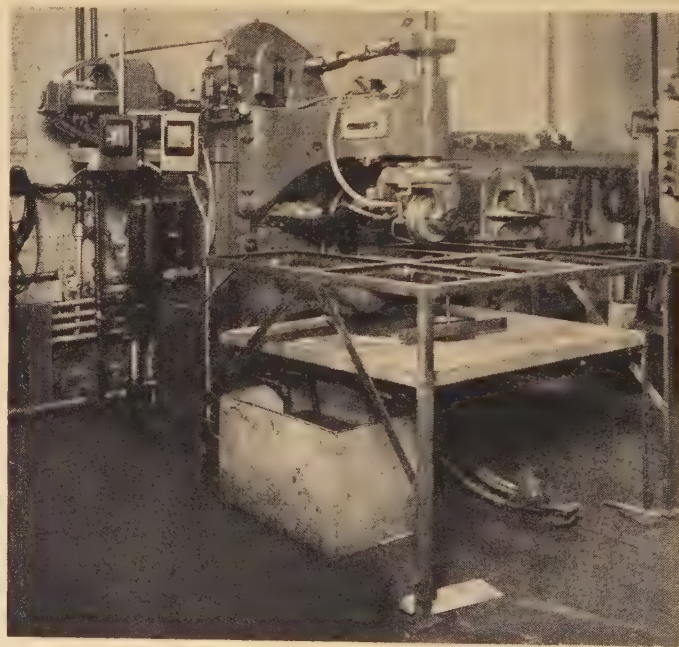


Figure 5. Line welder for developmental work

of 2,400 per minute. These are only examples of many such developments in the United States.

BUTT WELDING USED PRIMARILY FOR NONFERROUS METALS

The development of butt welding is proceeding almost as rapidly as that of other types of welding. Fully automatic butt welders are in operation for welding copper bull wire with diameters up to one inch for continuous lengths to draw into fine wire. These have fully calibrated dials to make possible rapid setup for various sizes of wire.

With these calibrations it is possible to change from one size of wire to another in a fraction of a minute and obtain satisfactory results without testing welds each time.

COPPER ALUMINUM BUTT WELDS

In many cases it is desirable to wind coils of aluminum for weight reduction. To facilitate assembly it sometimes is necessary to weld copper ends on the aluminum coil. These joints must be made by a special procedure to exclude brittle aluminum alloy from the joint. This pro-

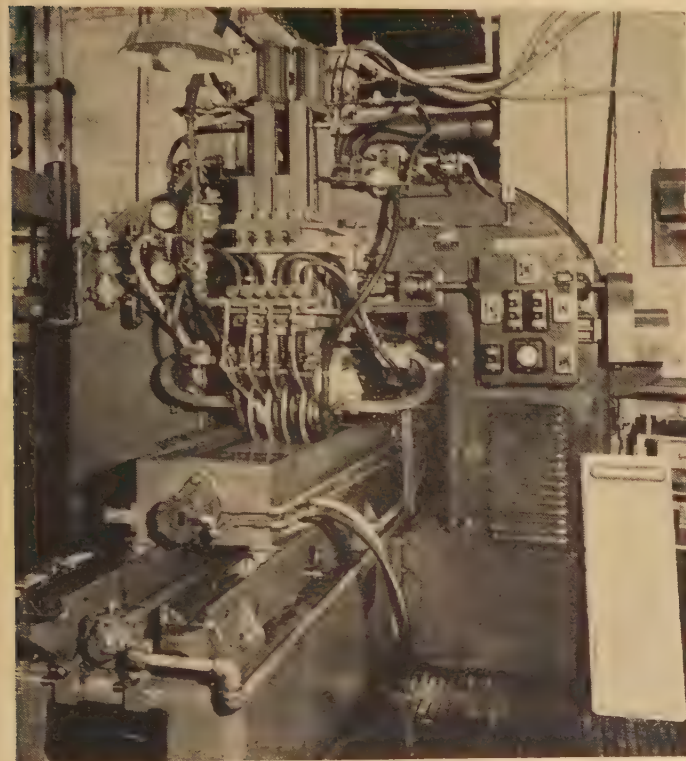


Figure 6. Front view of four-roll series seam welder with full automatic control, for intermittent seam welding of refrigerating-machine evaporators

cedure is explained in the patent for the process⁸ and also in a previous article by the author.⁹

FLASH BUTT WELDING

Flash butt welding is used primarily for ferrous metals and alloys. The developments in flash welding probably have been mechanical rather than electrical, and have been aimed toward higher-speed production and more completely automatic processes, to eliminate the human element.

Some outstanding flash welders have been built to weld the wide sheets in continuous strip steel mills to make continuous lengths for pickling and rolling. Some very high-speed flash welders have been built for the automotive and steel-barrel industries.

PORTABLE OR GUN WELDERS

Some of the recent developments in the use of portable or gun welders are of particular interest to the electrical

industry, as material of thickness ranging up to that of two pieces of three-eighths-inch steel is being fabricated by the use of pulsation welding with gun welders. All sorts of steel structures for frames, enclosing structures, and others for electrical purposes are being made by portable welders equipped with fully synchronous electronic control.

ELECTRIC SILVER-ALLOY BRAZING

The use of all types of resistance-welding equipment for brazing brings to brazing work the same degree of accuracy that is achieved in welding.

A great many parts made of copper that do not lend themselves to welding may be brazed with standard resistance welders equipped with accurate control and using tungsten or carbon facings on the electrodes.

Portable equipment for incandescent carbon brazing of wire and cable joints is also available. This type of equipment is capable of brazing joints in electrical conductors very rapidly and usually much more cheaply than they can be brazed with a torch or soft-soldered. These joints are more permanent than the soft-soldered joints and will stand much higher temperatures.

The use of resistance welding is growing very rapidly, as is shown by the following figures prepared by the Resistance Welding Manufacturers' Association.

Year	Approximate Kva Sold
1938.....	158,341
1939.....	189,885
1940 (to August 31).....	232,006

In addition, considerable equipment also is being built by some of the larger users of resistance-welding equipment.

The new resistance welders as built today are precision-type machine tools and should be operated as such.

With the correct selection of welding machine and control, competent supervision, trained operators, proper selection of thoroughly cleaned material, and careful design of parts to be welded, a high-quality product can be achieved by welding at a cost as low as or lower than that of any other method of fabrication.

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Three-Phase Systems With Unbalanced Wye-Connected Loads

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The various methods of solving three-phase unbalanced wye circuits, usually found separately in engineering literature, have been brought together here; each is illustrated by a specific example

WHILE methods for solving unbalanced systems have been in use for many years, applications and extensions of various forms of circuit analysis continue to appear. Evidence of this is given by the recent discussions in the "Letters to the Editor" columns of *ELECTRICAL ENGINEERING* on the unbalanced wye-circuit.^{1,2,3,4} Such discussions serve the very useful purpose of rounding out fundamental theory of the profession, and are of particular significance in the educational field where the attack on circuits first takes place. The discussions are of value in any of several ways: by adding to generalizations on existing forms of solution, by clarifying general methods, by illustrating certain approaches through specific example, and by simplifying the actual work required in handling a problem.

There is no one place, however, where one can find these many forms of solution grouped together. Textbooks are perhaps the best references for them, but any one textbook will contain only one or possibly two methods. Many books entirely omit treating unbalanced systems, or discuss the unbalanced delta circuit with no reference to the unbalanced wye.

The purpose of this article is to present in one place the applications of the many methods available in solving the three-wire unbalanced wye-circuit, and to illustrate each mode of solution by a specific numerical example. The article should have value in the field of education, and the following discussions should be of interest to students and instructors in their class work on circuits. In addition, however, the treatment should be of considerable value to the many in practice who occasionally meet with and must solve the type of problem described here. Although the attempt in practice almost always is to balance a system as nearly as possible, yet there are times at which a circuit is sufficiently unbalanced to require handling as such. There are also special circuits used in testing which are unbalanced wyes. One type of phase-rotation indicator, and the monocyclic circuit converting constant potential three-phase to constant current single-phase, again are examples of unbalanced wye-loads met in practice. To the writer's knowledge this article includes all the major methods that have been given in the past, in published form, for the unbalanced wye. The unbalanced delta is essentially a treatment of individual single phases, and

since the approach to it is well known this type is not discussed.

STATEMENT OF THE PROBLEM

Briefly stated, the usual conditions surrounding a problem on unbalanced circuits are:

- (a). A known set of impedances, or loads, and their circuit arrangement. The impedances may be unequal to each other in magnitude, in power factor, or in both.
- (b). A known three-phase supply. Usually the three line-to-line voltages are given, normally balanced. They may, however, be unbalanced in magnitude and in phase.

From these data one may wish to determine any one or several of the following quantities:

- (a). The line (or phase) currents.
- (b). The line-to-neutral voltages, or the residual voltage which exists between the common junction of the load elements and the neutral of the supply system.
- (c). The system power.
- (d). Phase relations between certain voltages and currents.

The circuit conditions for illustrative examples are given in figure 1 which shows an unbalanced wye-connected load receiving power from a three-wire three-phase supply. The line voltages are taken as 100 volts, and, with the ohmic values of the circuit elements, are chosen arbitrarily to give convenient magnitudes and phase angles in examples which appear later. These values are, however, fully representative of any such unbalanced system. Let the problem first be that of determining the line currents. From these any other desired information readily follows.

METHODS OF SOLUTION

The many methods of solution for the circuit of figure 1 are:

- (a). Calculating line currents directly from a system of simultaneous algebraic equations.⁵ Each line voltage is written as the sum of the impedance drops of the two phases between those lines.
- (b). Expressing the phase voltages, and hence the currents, in terms of two unknown scalars in quadrature^{6,7} which are evaluated first. The currents follow directly.
- (c). Calculating the residual voltage from the known line-to-neutral voltages of the supply and the impedances, or admittances, of the load elements.^{8,4,8,9,10} The phase voltages of the load follow, and then the currents. There are variations in this method.
- (d). Calculating the line-to-neutral voltages directly in terms of the line voltages and the impedances, or admittances, of the load

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1. For all numbered references see list at end of article.

elements. This scheme is an extension of method (c), both arising from the same system of equations.

(e). Superposition.⁹ The current distribution in the load elements is found for each generator phase voltage taken separately, the phase current being the sum of these components.

(f). Symmetrical components.^{5,7,9,11} The phase currents are expressed in terms of two balanced current systems of opposite phase sequence.

(g). Wye-delta transformation⁸ in which the original wye-load is replaced by an equivalent delta-connected set of impedances. The problem then is solved in the conventional way for the delta circuit.

ILLUSTRATIVE EXAMPLES

Each of these forms of solution now will be applied, in the order given, to the problem presented by figure 1. Since too many details often detract from the clarity of a presentation, in general only one current will be calculated the others being determined in like manner. Again, certain apparent and indicated intermediate algebraic steps in handling a problem are left to the reader. One usually derives much value from a discussion by carrying out some of the development and calculation himself.

Standard (counterclockwise) rotation of all vectors is used, and for reference at the start, let

$$\begin{aligned} Z_A &= 10/30 = 8.66 + j5 \text{ ohms} & Y_A &= 0.0866 - j0.05 \text{ mhos} \\ Z_B &= 10/-60 = 5 - j8.66 & Y_B &= 0.05 + j0.0866 \\ Z_C &= 10/0 = 10 + j0 & Y_C &= 0.1 + j0 \end{aligned}$$

and the voltages be

$$\begin{aligned} E_{NA} &= 0 + j57.74 \text{ volts} & E_{AB} &= 50 - j86.6 \text{ volts} \\ E_{NB} &= 50 - j28.87 & E_{BC} &= -100 + j0 \\ E_{NC} &= -50 - j28.87 & E_{CA} &= 50 + j86.6 \end{aligned}$$

These quantities appear constantly in the following developments and hence are available at this place for ready substitution. E_{BC} has been chosen along the horizontal axis, but it is realized, of course, that either of the other two line voltages could have occupied this position. The diagrams of connection and of voltage, both shown in figure 1, are two entirely different things, although at times it is helpful to some if they are similar in appearance.

The subscripts associated with voltages and currents are merely schemes of notation to be followed in obtaining magnitudes and proper phase angles of these quantities. Just so long as the same conventions and interpretations apply to all similar quantities, the scheme of notation is immaterial. Let us assume here that E_{AB} , for example, means that the direction of positive voltage is from A to B . In consequence of this,

$$E_{BA} = -E_{AB}$$

since E_{BA} is taken in the opposite sense of direction. Any phase voltage of the load, say E_{OA} , then is positive outward from the common junction. The relation between line and leg voltages is such that, for example,

$$E_{AB} = -E_{NA} + E_{NB} = -E_{OA} + E_{OB}$$

In adopting a convention for current flow, let the positive direction in the lines be from supply to load. This is the direction of energy transfer. Currents then are positive outward from the supply neutral, and at the load are positive inward toward the junction. Obviously, conven-

tions are arbitrary and positive current flow could be taken in the direction of O to A . At most a change in convention only reverses all voltages, or all currents, by 180 degrees on the final vector diagram for the complete system.

Method (a). Applying Kirchhoff's laws to the load circuit of figure 1, we may write

$$E_{AB} + I_A Z_A - I_B Z_B = 0 \quad (1)$$

$$E_{BC} + I_B Z_B - I_C Z_C = 0 \quad (2)$$

$$E_{CA} + I_C Z_C - I_A Z_A = 0 \quad (3)$$

and

$$I_A + I_B + I_C = 0 \quad (4)$$

Since any two of the voltage equations will yield the third, the four equations really constitute a set of three which involve the three unknown line currents.

Let I_C be desired. From equation 4, I_A is expressed in terms of I_B and I_C and then is eliminated from equation 3.

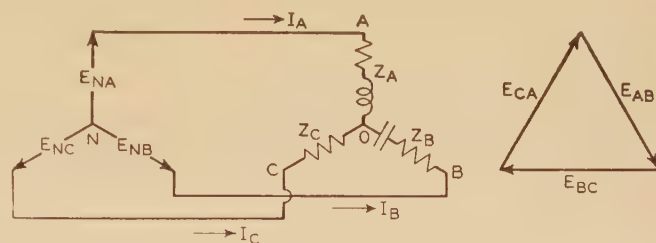


Figure 1. Unbalanced wye-connected load receiving power from a three-wire three-phase supply

This new voltage equation, and equation 2, are then solved simultaneously for either I_B or I_C , whence

$$I_C = \frac{E_{BC} Z_A - E_{CA} Z_B}{Z_A Z_B + Z_B Z_C + Z_C Z_A} \quad (5)$$

The intervening algebraic steps are elementary and direct, and therefore are omitted. Substitution of the complex quantity magnitudes for these voltages and impedances gives

$$I_C = -6.51 - j4.77 = 8.07 \text{ amperes}$$

The other currents are found in like manner.

This method is as straightforward as any. Whatever disadvantage it possesses is inherent in all calculations involving complex quantities—an error in sign or magnitude at times being hard to locate.

It might be remarked at this point that although but one current, equation 5, is given in symbolic form, the others can be written from this one by inspection. One has but to note the cyclic order and appearance of the subscripts of the quantities concerned. These same statements hold for other current and voltage equations that are to appear.

Method (b). Let the neutral point O of the load be shown as in figure 2. Its exact location is not yet known, of course, but it may be assumed at any position for the

time being. With point *A* as a reference, the three phase voltages are

$$\begin{aligned} E_{OA} &= -a + jb \\ E_{OB} &= (50 - a) - j(86.6 - b) \\ E_{OC} &= -(50 + a) - j(86.6 - b) \end{aligned} \quad (6)$$

whence the currents become

$$\begin{aligned} I_A &= \frac{E_{OA}}{Z_A} = \frac{-a + jb}{8.66 + j5} = -0.0866a + 0.05b + j0.05a + j0.0866b \\ I_B &= \frac{E_{OB}}{Z_B} = \frac{(50 - a) - j(86.6 - b)}{5 - j8.66} \\ &= 10 - 0.05a - 0.0866b - j0.0866a + j0.05b \\ I_C &= \frac{E_{OC}}{Z_C} = \frac{-(50 + a) - j(86.6 - b)}{10} = -5 - 0.1a - j8.66 + j0.1b \end{aligned} \quad (7)$$

Since the sum of the currents is zero, the sum of the real components must equal zero, and so also must the sum of the imaginary components. Thus,

$$\begin{aligned} -0.2366a - 0.0366b + 5 &= 0 \\ -j0.0366a + j0.2366b - j8.66 &= 0 \end{aligned} \quad (8)$$

from which $a = 15.10$ and $b = 38.95$. The currents now are obtained readily, and

$$I_C = -5 - 1.51 - j8.66 + j3.90 = -6.51 - j4.76 \text{ amperes}$$

It will be observed that upon evaluation of the scalars a and b , all currents and phase voltages can be calculated

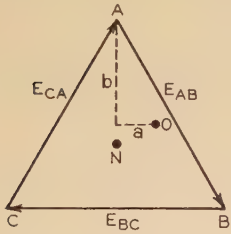


Figure 2. Voltage diagram showing co-ordinates of assumed floating neutral, point *O*

immediately. Also, these scalars locate the neutral point *O*. The shift from its position *N*, under balanced conditions is

$$E_{NO} = 15.1 + j18.8 \text{ volts}$$

N is, of course, at the geometric center of the triangle of line voltages.

While point *A* has been chosen as reference, any other reference point could just as well have been selected. Were *N* to have been the reference position, a and b then would give in themselves the shift of *O* from *N*, that is, $E_{NO} = a + jb$.

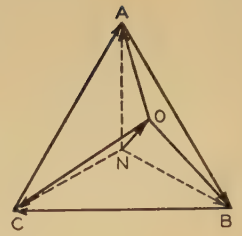
Method (c). As in the previous method, let *O* be chosen at any point. On such an assumption, figure 3 thus shows the complete voltage diagram for the system. The actual phase voltages are E_{OA} , etc.; the phase voltages for balanced loads are E_{NA} , etc.; and the residual voltage, or shift of the neutral, is E_{NO} .

By aid of figure 3,

$$\begin{aligned} I_A &= \frac{E_{OA}}{Z_A} = E_{OA} Y_A = (E_{NA} - E_{NO}) Y_A \\ I_B &= (E_{NB} - E_{NO}) Y_B \\ I_C &= (E_{NC} - E_{NO}) Y_C \end{aligned} \quad (9)$$

Since the sum of the currents is zero, addition of the right

Figure 3. Voltage diagram showing phase and line voltages of load and residual voltage E_{NO}



hand members of equations 9 yields a single expression involving but the one unknown E_{NO} . Thus

$$\begin{aligned} E_{NO} &= \frac{E_{NA} Y_A + E_{NB} Y_B + E_{NC} Y_C}{Y_A + Y_B + Y_C} \\ &= 15.13 + j18.77 \text{ volts} \end{aligned} \quad (10)$$

upon substitution for the known voltages and admittances.

Consequently, from equations 9, the actual voltages across the load elements are found. For example,

$$\begin{aligned} E_{OC} &= (E_{NC} - E_{NO}) \\ &= (-50 - j28.87) - (15.13 + j18.77) \\ &= -65.13 - j47.64 \text{ volts} \end{aligned} \quad (11)$$

and

$$I_C = E_{OC} Y_C = -6.51 - j4.76 \text{ amperes}$$

Another approach⁴ by way of the residual voltage method is as follows. Were a zero impedance connection to exist between the two neutral points, *N* and *O* (they would now be the same point on a voltage diagram), the neutral current could be obtained readily as the vector sum of the three leg currents. If a voltage were inserted in the neutral lead so as to force an equal but opposite current through it, and thence through the three load impedances in parallel, the resultant neutral current would be zero, as is the case when *O* and *N* are not tied together. Now E_{NO} is that voltage and it can be calculated in such a manner. It is merely the product of the initial neutral current for an assumed neutral connection and the equivalent impedance of the three loads in parallel.

For the problem under discussion,

$$I_{ON} = -2.89 - j5 \text{ amperes}$$

if *N* and *O* are connected. Hence

$$\begin{aligned} E_{NO} &= I_{NO} Z_{\text{equiv}} = I_{NO} / (Y_A + Y_B + Y_C) \\ &= (2.89 + j5) / (0.2366 - j0.0366) \\ &= 15.13 + j18.77 \text{ volts} \end{aligned}$$

This last method of solution can be handled very nicely by graphics if one desires.

It should be pointed out here that there is a fundamental similarity between methods (b) and (c). If *N* is chosen as the reference point in method (b), equations 7 and equations 9 are essentially the same, since, for example,

$$E_{OA} = E_{NA} - E_{NO} = E_{NA} - (a + jb)$$

Method (d). Extending the previous method, the voltages across the load elements can be expressed directly in terms of the known line voltages and the load admittances. Thus, substituting E_{NO} of equation 10 in equation 11, we have,

$$\begin{aligned} E_{OC} &= \frac{E_{BC} Y_B - E_{CA} Y_A}{Y_A + Y_B + Y_C} \\ &= -65.1 - j47.7 \text{ volts} \end{aligned} \quad (12)$$

when the indicated calculations are fully carried out. Consequently,

$$I_C = E_{OC} Y_C = \frac{E_{BC} Y_B Y_C - E_{CA} Y_A Y_C}{Y_A + Y_B + Y_C} \quad (13)$$

$$= -6.51 - j4.77 \text{ amperes}$$

Methods (c) and (d) may be thought of as treatments by superposition in which the current distribution due to the system of voltages E_{NA} , etc., is added to that for the residual voltage E_{NO} . The algebraic analysis, however, sidesteps any requirement of actually calculating the two distributions of current.

Comparison of equations 5 and 13 show them to be the same, if substitution is made of reciprocal admittances for the impedances, or vice versa.

Method (e). While the algebra of the two previous analyses pointed to superposition, actual current components were not determined. One can solve the unbalanced wye, however, strictly by superposition. Take first the phase voltage E_{NA} of the supply, this voltage acting on the impedance Z_A in series with the parallel combination of Z_B and Z_C . The complete current distribution in the system is found for this arrangement. Next E_{NB} is applied to Z_B in series with the parallel combination of Z_A and Z_C , and a second current distribution found. Lastly, E_{NC} gives rise to its system of currents. Addition of the three separate current components in each leg of the load yields the resultant line currents.

Although this method is a possibility, it is not so straightforward as are the other schemes, and the great number of calculations with complex quantities makes it tedious. However, to show the application here, I_C is found by this method of analysis.

The impedance of the path to which E_{NA} is applied is

$$Z_A = Z_A + (Z_B Z_C) / (Z_B + Z_C) = 13.66 + j2.11 \text{ ohms}$$

Similarly, for E_{NB} and E_{NC} , respectively,

$$Z_B = 10 - j7.32$$

and

$$Z_C = 16.83 - j1.83$$

Due to E_{NA} , the current through Z_A is $(0.639 + j4.13)$ amperes, with the component $-(1.51 + j1.88)$ amperes through Z_C . Due to E_{NB} , the current component through Z_C is found similarly to be $-(2.24 + j0.88)$, and by virtue of E_{NC} there exists $-(2.75 + j2.01)$ amperes in Z_C . Conventions on direction of current flow through Z_C introduce the negative signs for the first two components. The sum of the three currents therefore is

$$I_C = -6.50 - j4.77 \text{ amperes}$$

Method (f). A development of the method of symmetrical components is beyond the scope of this discussion, and it is hoped that the reader will refer to the subject in one of the standard textbooks for further information on it. Three of the many sources available are the books named in references 5, 7, and 9.

It is sufficient here to state that any three-phase voltage or current system, unbalanced and unsymmetrical, can be resolved into three component systems. The first (positive-sequence) system is balanced and of the same se-

quence as the initial system. The second (negative-sequence) system also is balanced but has the opposite phase sequence, while the third (zero-sequence) system is given by three equal vectors having the same phase position. Let these component systems be designated respectively by the subscripts 1, 2, and 0.

Remembering that the three vectors of a balanced system are 120 degrees apart, by introducing the unit operator a ,

$$a = 120\text{-degree operator} = -0.5 + j0.866$$

$$a^2 = -0.5 - j0.866, \quad a^3 = 1 + j0$$

any two of the three vectors can be written in terms of the third, which then might be called the reference vector for that voltage or current system. The operator a (Karapetoff calls it a "turning operator") is similar to the 90-degree operator j , and by means of it we can write I_1 , $a^2 I_1$, and $a I_1$ for the positive sequence currents in, say, lines A , B , and C , respectively. Likewise, the negative sequence currents are I_2 , $a I_2$, and $a^2 I_2$. The three zero sequence currents are all I_0 .

For an unsymmetrical current system, therefore,

$$\begin{aligned} I_A &= I_1 + I_2 + I_0 \\ I_B &= a^2 I_1 + a I_2 + I_0 \\ I_C &= a I_1 + a^2 I_2 + I_0 \end{aligned} \quad (14)$$

The problem lies in determining the magnitudes and positions of the reference components I_1 , I_2 , and I_0 . Note that while the components in line A have been chosen above as the reference currents, they can just as well be assigned to either of the other lines. Furthermore, it is not necessary that the reference currents exist together in the same line. Figure 4 shows the voltage and current systems for the problem at hand in terms of the operator a . In this case, since we are interested first in I_C , let line C be chosen to

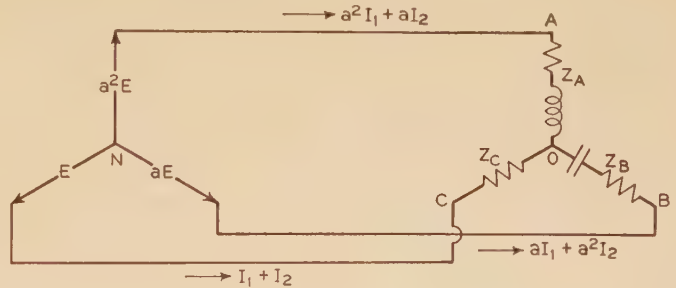


Figure 4. Supply voltages and current components for solution by method of symmetrical components

carry the reference currents, and E_{NC} be taken as the reference voltage E . Only positive and negative sequence currents can exist in the lines, because zero sequence currents cannot flow without a neutral lead. The supply voltages are balanced, hence in themselves they form only a positive sequence voltage system.

The voltage between B and C is $(E - aE)$, and equating this to its components for the two adjacent legs, we have

$$E - aE = (I_1 + I_2) Z_C - (a I_1 + a^2 I_2) Z_B$$

Similarly, between A and C ,

$$E - a^2 E = (I_1 + I_2) Z_C - (a^2 I_1 + a I_2) Z_A$$

Substituting complex quantity magnitudes for the voltage, the operator, and the impedances, the two equations just given become

$$\begin{aligned}-100 &= (5-j8.66)I_1 + 20I_2 \\ -50-j86.6 &= (10+j10)I_1 + (18.66-j5)I_2\end{aligned}$$

from which

$$\begin{aligned}I_1 &= -4.27-j3.90 \\ I_2 &= -2.24-j0.87\end{aligned}$$

and

$$I_C = I_1 + I_2 = -6.51-j4.77 \text{ amperes}$$

Application of symmetrical components to this type of problem is basically the same scheme as method (a). $(E-aE)$ replaces E_{BC} , etc., for the voltages between terminals, and the line currents are given by two components. The circuit equations are the same in form, although only two are required here for determination of the unknowns I_1 and I_2 . While the method of symmetrical components as applied here has no great advantage over other methods already described, its use may have considerable appeal for those who understand it.

Method (g). Lastly, the given wye set of impedances can be replaced by an equivalent set of impedances in delta and the current in any line found as the sum of the currents in the two adjacent legs of the delta. In this scheme of transformation, the impedances of the delta circuit between any two lines is made equal to the impedance of the wye circuit between the same lines. Thus, referring to figure 5, between lines A and B ,

$$Z_Y = Z_A + Z_B = Z_\Delta = \frac{Z_{AB}(Z_{BC} + Z_{CA})}{Z_{AB} + Z_{BC} + Z_{CA}}$$

Similar equations are written for the impedances between lines B and C and between lines C and A . We therefore have three equations that are solved simultaneously for the delta or the wye impedances. The transformation can be carried either way, one set of impedances forming the initial data.

For the problem at hand,

$$\begin{aligned}Z_{AB} &= \frac{Z_A Z_B + Z_B Z_C + Z_C Z_A}{Z_C} = \frac{\Sigma ZZ}{Z_C} \\ &= 22.32-j8.66 \text{ ohms}\end{aligned}$$

when the substitutions are made and the indicated steps carried out. Similarly,

$$Z_{BC} = \frac{\Sigma ZZ}{Z_A} = 14.99-j18.66$$

and

$$Z_{CA} = \frac{\Sigma ZZ}{Z_B} = 18.66+j14.99$$

Now

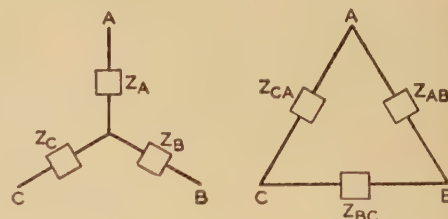
$$\begin{aligned}I_C &= \frac{E_{BC}}{Z_{BC}} - \frac{E_{CA}}{Z_{CA}} \\ &= \frac{-100}{14.99-j18.66} - \frac{50+j86.6}{18.66+j14.99} \\ &= -(2.62+j3.26) - (3.89+j1.51) \\ &= -6.51-j4.77 \text{ amperes}\end{aligned}$$

Again, this form of attack offers no advantage over earlier schemes. One difficulty, met immediately, is the great amount of complex-quantity algebra which may be introduced in calculating the equivalent impedances.

OTHER CIRCUIT QUANTITIES

In the several methods of calculation on the load system of figure 1, only the one current I_C was found. The same methods, however, apply exactly to the determination of the other two currents. Once the line currents are obtained, the phase voltages (if they are not known already

Figure 5. Notation on impedances for wye-delta transformation



through the particular method employed) become available immediately, and with them the phase angles between leg currents and voltages. The system power is simply the sum of the I^2R losses for the three legs, or can be found as the sum of two wattmeter readings in the conventional way.

To complete the story, the load currents and voltages are:

$$\begin{aligned}I_A &= 0.64+j4.12 \text{ amperes} & E_{OA} &= -15.1+j39.0 \text{ volts} \\ I_B &= 5.87+j0.64 & E_{OB} &= 34.9-j47.6 \\ I_C &= -6.51-j4.77 & E_{OC} &= -65.1-j47.7\end{aligned}$$

GENERAL COMMENTS

The methods illustrated are equally adaptable to unbalanced loads taking power from an unbalanced voltage supply. No modifications whatever are necessary except in the case of symmetrical components, in which the supply voltage then is resolved into its component systems. For some of the other methods, depending upon the particular one in view, knowledge may be required on the position of the neutral of the supply, or, what is equivalent, on the phase voltages of the supply. It should be apparent that the balanced circuit, which is but a special case, is included in any discussion on the unbalanced system.

Reversed phase rotation will produce a second set of load currents and voltages for the phases, these new values in general differing from the ones calculated here. The problem may be approached by interchanging any two phase voltages and from them obtaining expressions for the new line voltages, or by interchanging directly any two line voltages. These steps are equivalent. Again, phase and line voltages can be left as they stand initially, the phase rotation reversed by considering actual reversal of the generator which produces these voltages. Clockwise angles now become positive, whence all the impedances

$$Z = R + jX$$

are changed to

$$Z = R - jX$$

In any case, the steps from this point on are identical with those shown in the methods described. These various treatments with reversed rotation yield among themselves the same magnitudes of voltages, currents, and phase angles, but one method may show an angular shift, forward or backward, of the complete vector diagram of all quantities with respect to the diagram for another method.

Specifically, interchanging E_{NB} and E_{NC} , for example, we have

$$\begin{array}{ll} E_{NA} = 0 + j57.74 \text{ volts} & E_{AB} = -50 - j86.6 \text{ volts} \\ E_{NB} = -50 - j28.87 & E_{BC} = 100 + j0 \\ E_{NC} = 50 - j28.87 & E_{CA} = -50 + j86.6 \end{array}$$

whence the new line currents are

$$\begin{array}{l} I_A = 1.28 + j8.26 \text{ amperes} \\ I_B = -3.26 - j7.39 \\ I_C = 1.98 - j0.87 \end{array}$$

While there are other extensions, of course, in the entire treatment on unbalanced systems, they are not included in the scope of this article. The aim has been to present general methods of attack on a very common problem. Of the several methods described, the last three may not be so satisfactory as are the others. They possess no advantages over the first four schemes, and are more indirect. Of the first four methods, personal appeal more often than not may determine which will be chosen. The quantity primarily desired—line current, leg voltage, or

shift of the neutral from balanced loading—also may influence the selection of the method adopted. Again, the tools—such as the vector slide rule—used in calculating numerical results may make one scheme appear more suitable than others.

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12. ELECTRIC CIRCUITS (book), Electric Engineering Staff, Massachusetts Institute of Technology. John Wiley and Sons, 1940. This book, appearing subsequent to the initial development of the foregoing article, describes several of the methods given here.

The Colorado-Big Thompson Project

CULMINATING 50 years of effort on the part of the people of Colorado to secure additional irrigation water for northeastern Colorado, the Colorado Big Thompson project entered the construction stage in December 1938. A Bureau of Reclamation project, the general plan of the complete development from the standpoint of future operation, will extend from the vicinity of Kremmling on the western slope of the Continental Divide to Julesburg and the state line on the eastern slope.

The principal purpose of this project is to furnish annually an estimated 320,000 acre-feet of western-slope water for 615,000 acres of Colorado farm land on the eastern slope. This water will be delivered to existing eastern slope irrigation systems to complete the moisture requirements of the growing season. As a secondary purpose, the project will be capable of supplying annually 360,000,000 kilowatt-hours of firm hydroelectric energy and 332,000,000 kilowatt-hours of secondary energy. This energy will be available to markets in the vicinity after the deduction of sufficient energy to operate the project.

Five reservoirs, six power plants, two pumping plants, and a 13-mile tunnel comprise the major engineering units

in the project. The reservoirs will range in capacity from 50,000 to 483,000 acre-feet and will be formed by a series of earth-fill dams ranging in height from 128 to 270 feet. The six hydroelectric plants will have capacities ranging from 16,000 to 50,000 kw and will operate under heads of some 250 to 1,200 feet. The 13-mile tunnel will have a cross-sectional diameter of 9.75 feet inside of concrete lining and will be constructed with a constant slope from west to east. Of sufficient capacity to satisfy the annual diversion requirements and augmented by sufficient storage facilities on the eastern slope, the small-size tunnel can provide a maximum amount of firm hydroelectric energy through continuous operation.

Two of the five reservoirs will be on the western slope. With the western-slope replacement storage thus provided by the project, all water diverted will be in excess of present and future requirements for lands on the western slope. Western-slope water for diversion to the eastern slope will be pumped from the upper of the two western-slope reservoirs to a storage lake at the western end of the 13-mile tunnel. Off-peak power from two of the six power plants will be used for the pumping operation.

The project also requires the construction of a series of canals, closed conduits, and syphons connecting the various units.

From an article of the same title by M. S. Bitner, associate engineer, Bureau of Reclamation, and published in the Reclamation Era, September 1940, pages 267-9.

Institute Activities

National

Radio Programs on Defense Work Sponsored by AIEE

Enlistment of the far-reaching resources of the electrical engineering profession in the Army, the Navy, and in defense production has been selected as the subject of a series of Monday night broadcasts sponsored by the AIEE over the "blue network" of the National Broadcasting Company. These 15-minute programs run from 7:45 to 8:00 p.m. (Eastern Standard Time). The first program originated in Philadelphia, January 27, 1941, the opening day of the AIEE winter convention. Subsequent broadcasts will be from NBC studios in New York. The broadcast series was arranged through the educational division of NBC.

Participating in the first program were Doctor R. W. Sorensen, president of the Institute; J. V. B. Duer, chief electrical engineer of the Pennsylvania Railroad; N. E. Funk, vice-president in charge of engineering, Philadelphia Electric Company, and Joseph W. Barker, dean of engineering, Columbia University. This broadcast was concerned with the part being taken by the electrical engineer in the nation's power and communication facilities and transportation systems.

The second program, February 3, describing the part played by the electrical engineer in the Army, is scheduled to include an interview with General J. O. Mauborgne, chief signal officer, United States Army. The third will tell how the resources of the electrical engineer have been utilized by the Navy. Succeeding broadcasts will relate to the participation of the electrical engineering profession in making America strong by steadily increasing its production, speeding up research, and expanding its technical facilities. The following have been scheduled to date:

January 27. Contributions of the Electrical Engineer to National Defense

February 3. The Electrical Engineer in the Army

February 10. The Electrical Engineer in the Navy

Future AIEE Meetings

Great Lakes District Meeting
Fort Wayne, Ind., April 23-25, 1941

North Eastern District Meeting
Rochester, N. Y., April 30-May 2, 1941

Summer Convention
Toronto, Can., June 16-20, 1941

Pacific Coast Convention
Yellowstone National Park, August 27-29, 1941

February 17. The Electrical Engineer in Defense Production

February 24. Mobilizing Electric Power for Defense

March 3. Electrical Research for Defense

Winter Convention Report to Appear in March Issue

As this issue goes to press the Institute's 1941 winter convention gets under way at Philadelphia, Pa. Early indications are that this first winter convention since 1924 to be held outside New York City is continuing the successful record of recent years. Registration for the first two days totaled 1,278, as compared with 1,178 for the first two days of the 1940 convention, 1,159 for 1939, and 1,027 for 1938. The March issue will contain the full report of the convention.

Personal

C. W. Franklin (M'24) formerly assistant electrical engineer, Consolidated Edison Company of New York, Inc., New York, N. Y., has been made electrical engineer. Among other changes resulting from recent organizational shifts in Consolidated Edison, J. E. Goodale (A'21, F'34) formerly manager of the substation operation department, has been made assistant electrical engineer; J. A. Brooks (A'25, F'34) formerly distribution engineer, is now manager of substation operation, and G. T. Minasian (A'25, M'30) succeeds Mr. Brooks. S. A. Warner (A'27, M'30) has been made assistant distribution engineer, his former position of assistant outside plant engineer having been taken over by J. E. McCormack (A'27, M'37) formerly division engineer. L. K. Murphy (A'29) formerly manager of the construction contracts bureau, now heads the purchasing and stores department as purchasing agent; Pincus Spiller (A'38) former manager of the electrical equipment bureau, is now assistant purchasing agent; and George Sutherland (A'20, F'27) former assistant manager of the outside plant construction department, is now general stores manager. J. F. Mulligan (A'29, M'37) former superintendent, transmission division, is now general superintendent, installation and apparatus bureau (formerly apparatus maintenance division) of the electric distribution construction department (formerly distribution construction department). A. R. Collard (A'36) formerly superintendent of the consumers and emergency division, Manhattan and Bronx, is now assistant general superintendent of the underground bureau. Ferdinand Zogbaum (A'09, M'15) formerly co-ordinating engineer, is now assistant to the manager of

the contract inspection department (formerly contract control and inspection department). J. J. Ryan (A'37) formerly assistant general superintendent of the distribution operation department, is now general superintendent of the combined gas and electric meter divisions, which have been added to the department. R. F. Brower (M'34) former assistant system engineer, system engineering department, has been made system engineer. L. E. Frost (A'22, M'30) formerly assistant to vice-president in charge of research development and planning, is now research and development engineer, heading the research and development department.

H. M. Hobart (A'94, F'12) has retired as consulting engineer, General Electric Company, Schenectady, N. Y., and will engage in private consulting practice. He was born in Boston, Mass., November 29, 1868, and received the degree of bachelor of science in electrical engineering from Massachusetts Institute of Technology in 1889. He entered the employ of the Thomson-Houston Electric Company, Lynn, Mass., in 1889, was transferred to General Electric Company at Schenectady during 1894-95, and returned to Lynn the following year. From 1896 to 1900 he was with the British Thomson-Houston Company, London, England, and from 1900 to 1903 with the Union Electricitats Gesellschaft, Berlin, Germany. During the next eight years he carried on private consulting practice in London, returning to General Electric Company in 1911 as consulting engineer, in which position he continued until his recent retirement. He received the Samuel Wylie Miller Medal of the American Welding Society in 1936. He is author and co-author of a number of books and articles, and holder of some 30 patents, some in collaboration. He has served the Institute as a manager (1922-26), vice-president (1926-28), on various committees and as representative on other organizations, notably the United States National Committee of the International Electrotechnical Commission (1914-32). He has been particularly active in standards work, and is also a member of the American Welding Society, American Society of Mechanical Engineers, American Association for the Advancement of Science, and of the British Institutions of Civil Engineers, Electrical Engineers, and Mechanical Engineers.

H. V. Putman (A'23, M'32) formerly manager of engineering, transformer works, Westinghouse Electric and Manufacturing Company, Sharon, Pa., has been appointed manager of the transformer division. A native (1899) of Barker, N. Y., he received the degrees of bachelor of science in electrical engineering, 1920, master of science, 1921, and doctor of philosophy, 1923, from

Union College. After two years with the Ideal Electric and Manufacturing Company, Mansfield, Ohio, he joined the Westinghouse company in 1925, becoming section engineer in 1928, and manager of engineering in 1931. **J. K. Hodnette** (A'25, M'30) former transformer development engineer, has been appointed manager of engineering, transformer division, Sharon. He has been with the Westinghouse company since 1923, and a transformer engineer since 1925. **H. B. West** (A'24) former division engineer, has been appointed manager of manufacturing in the transformer division at Sharon. He joined the Westinghouse company in 1919, and since 1935 has had charge of instrument and regulator engineering.

H. V. Bozell (A'08, F'23) formerly vice-president, General Telephone Corporation, New York, N. Y., has been elected president of that company. Born at Beloit, Kans., May 31, 1886, he received the degrees of bachelor of science in electrical engineering, 1908, and electrical engineer, 1915, from the University of Kansas. From 1908 to 1916 he was successively assistant professor, associate professor, and professor of electrical engineering, University of Oklahoma, Norman, and from 1916 to 1921 assistant professor of electrical engineering, Yale University, New Haven, Conn. In 1920 he also became co-editor of *Electric Railway Journal*, published by the McGraw-Hill Publishing Company, New York, N. Y., continuing with the company as first editor of *Bus Transportation*, and from 1922 to 1925 as co-editor of *Electrical World*. He went with Bonbright and Company, investment bankers, in 1925, and in 1932 became vice-president of Associated Telephone Utilities Company, predecessor of General Telephone corporation.

P. O. Langguth (A'28) formerly design engineer, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., has been appointed assistant manager, circuit breaker and protective devices engineering, switchgear division. He has been with the company since 1924 and formerly was in charge of small oil circuit-breaker engineering. **H. J. Lingal** (A'33) formerly section engineer, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., has been given special assignments in connection with large oil circuit breakers, switchgear division. **A. J. A. Peterson** (A'16, M'30) former manager of circuit breaker engineering, switchgear division, has been made project section engineer, switchboard engineering, switchgear division. Other changes in the switchgear division include the appointment of the following as section engineers, circuit breaker and protective devices engineering: **R. C. Dickinson** (A'37), **G. G. Grissinger** (M'38), **A. W. Hill** (A'38), **W. M. Leeds** (A'32, M'38), **H. L. Rawlins** (A'30), **H. M. Wilcox** (M'27).

C. H. Taylor (A'07, M'24) has retired as vice-president in charge of engineering, RCA Communications, Inc., New York, N. Y. Born August 22, 1875, at Hayes,

Middlesex, England, he received his technical education at Heriot Watt College, Edinburgh, Scotland. He was employed by New and Mayne, Ltd., B. F. Sturtevant Company, Wireless Telegraph and Signal Company, and Evershed and Vignoles, Ltd., in England, before coming to the United States in 1902, when he joined the Marconi Wireless Telegraph Company of America. He engaged in the construction and operation of radio stations in various parts of the United States and in Brazil, and supervised construction of the transoceanic stations built along the Atlantic and Pacific coasts and in Hawaii. When the Radio Corporation of America was formed in 1920 he became its acting chief engineer, and in 1924 was made chief communications engineer. He was later appointed vice-president of RCA Communications, Inc.

H. H. Beverage (A'23, M'34) chief research engineer, RCA Communications, Inc., New York, N. Y., has been made vice-president in charge of research and development. Born at North Haven, Maine, October 14, 1893, he received the degree of bachelor of science in electrical engineering in 1915 from the University of Maine which awarded him the honorary degree of doctor of engineering in 1938. He went with General Electric Company, Schenectady, N. Y., in 1915, and after a year on general testing became radio laboratory assistant. In 1920 he was placed in charge of radio research on communication equipment for Radio Corporation of America. He was transferred to RCA Communications, Inc., in 1929, as chief communications engineer, and since 1932 has been chief research engineer in charge of the research staff. In 1923 he was awarded the Morris Liebman Memorial Prize of the Institute of Radio Engineers. He is a past president of that society.

W. C. Smith (A'07, F'40) formerly engineer, San Francisco, Calif., office, General Electric Company, has been made district engineer, Pacific district. He entered the General Electric test course in 1905, and was transferred to transformer engineering in 1907. In 1920 he went to San Francisco as transformer specialist, and in 1932 became engineer of that office. **O. A. Gustafson** (A'25) formerly central station engineer, Los Angeles, Calif., becomes district central station engineer. He has been with General Electric since 1923, first at Schenectady, and since 1928 at Los Angeles. **R. C. Brosemer** (A'21, M'37) formerly assistant engineer, San Francisco office, has been made district industrial engineer. He joined the test course at Schenectady in 1925, was transferred to San Francisco in 1929, and has been assistant engineer since 1937.

C. F. Terrell (A'10, M'18) formerly operating manager of the Gulf States Utilities Company, Beaumont, Tex., has been appointed operating manager of Puget Sound Power and Light Company, Seattle, Wash., with duties including management of the central station division, and supervision of the system's generation, transmission, and distribution. First employed in 1903 by

the Seattle Electric Company, one of the predecessors of Puget Sound Power and Light, he was made superintendent of light and power for the latter's northwest division, Bellingham, Wash., in 1922. In 1924 he became superintendent of light and power for the El Paso (Tex.) Electric Company, and was later general superintendent of the Tampa (Fla.) Electric Company, before going with Gulf States Utilities in 1929.

Fred Elwell (A'27) has retired as superintendent of hydroelectric power plants, British Columbia Electric Railway Company, Vancouver, B. C., Canada. Born February 14, 1874, at Horsham, Sussex, England, he was employed an apprentice in 1892 by Frank Suter and Company, electrical engineers, London, later becoming superintendent of construction. Coming to Canada in 1898, he became assistant superintendent and later superintendent of the Bonnington Falls, B. C., power plant of the West Kootenay Power and Light Company. He was employed by British Columbia Electric Railway Company in 1911 as superintendent of the powerhouse at Lake Buntzen, and was made superintendent of power plants in 1925.

J. O. Johnson (A'36) formerly assistant material engineer, United States Navy, Brooklyn, N. Y., has been appointed chief engineer of Industrial Manufacturers, Inc., Elizabeth, N. J. Born June 20, 1909, at Middlesex, Vermont, he received the degree of electrical engineer at Rensselaer Polytechnic Institute in 1931. He was employed by Sears, Roebuck and Company, Chicago, Ill., from 1931 to 1933, first on testing, and later as research and design engineer in the merchandise development division. He became junior material engineer in the electrical section of the material laboratory of the United States Navy Yard, Brooklyn, in 1934, and later assistant material engineer.

J. W. Barker (M'26, F'30) dean of engineering, Columbia University, New York, N. Y., has been elected a member of the executive committee of the council of American Association for the Advancement of Science, for a four-year term. Dean Barker has been active in Institute affairs for many years. He is current chairman of the AIEE technical program committee and committee on award of Institute prizes, and is a member of several other committees; he was chairman of the committee on education 1937-39. He is also a member of several other technical societies, and has been active in the division of engineering and research of National Research Council.

N. H. Callard (A'16) formerly sales counselor, Westinghouse Electric and Manufacturing Company, Pittsburgh, Pa., has been appointed manager of distribution apparatus, agency sales department. He has been with the company since joining the apprentice course in 1912, except for Army service during the World War, and has served as salesman for the Salt Lake City, Utah, office, on syndicate operations in New York, N. Y., and from 1928 to 1939 as district central station manager on the

Pacific Coast. He recently has been engaged on staff assignments in the general sales department at Pittsburgh.

T. A. Abbott (A'26, M'31) formerly sales engineer, General Electric Company, Schenectady, N. Y., has been appointed manager of sales, meter division. He was a member of the General Electric test course 1925-26, and after five years as instructor in electrical engineering at Yale University, New Haven, Conn., he returned to the company in 1931 to take charge of meter and instrument courses in the meter engineering department at Lynn, Mass. He became superintendent of the meter department in 1937 and in 1940 was transferred to meter sales at Schenectady.

J. H. Edwards (M'20) associate editor, *Coal Age*, McGraw-Hill Publishing Company, Inc., has been appointed electrical editor of *Engineering and Mining Journal*, also a McGraw-Hill publication. He continues in his former capacity with *Coal Age*, with headquarters for both at Huntington, W. Va. He has been with *Coal Age* since 1924, having previously been engaged in electrical work for the Chicago, Rock Island, and Pacific Railway Company, Silvis, Ill., 1913-18, and the Elkhorn Piney Coal Mining Company, Huntington, 1918-24.

W. R. MacDonald, Jr. (A'33) editorial assistant, American Institute of Electrical Engineers, New York, N. Y., has been ordered to active duty as first lieutenant in the Signal Corps, United States Army, with headquarters at Washington, D. C. He has held a commission in the Signal Corps Reserve since 1932. A native (1910) of New York, he received the degree of electrical engineer from Cornell University in 1932. He has been employed in the editorial department of the Institute since 1934.

Donald Fisher (A'35) formerly division plant superintendent, Division 1, New York, N. Y., long lines department, American Telephone and Telegraph Company, has been appointed engineer of outside plant. **G. H. Quermann** (A'22) formerly division plant superintendent, Division 5, St. Louis, Mo., has been appointed general plant superintendent, southern. **J. W. Creasy** (A'20, M'29), engineer of outside plant, New York, N. Y., becomes division plant superintendent, St. Louis.

C. V. Aggers (A'39) former liaison engineer, engineering laboratories and standards department, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., has been made manager of manufacturing and engineering, Westinghouse X-Ray Company, Long Island City, N. Y. A native (1905) of Franklin, Pa., he has been with the Westinghouse company since 1925, in various departments, and has been liaison engineer since 1937.

C. C. Shutt (A'28) formerly manager of engineering, small motors division, Westinghouse Electric and Manufacturing Company, Lima, Ohio, has been made manager of the small motors division. He was born in 1902 and received the degree of bachelor of science in electrical engineering from Iowa State College in 1926. He entered the

Westinghouse graduate course immediately after graduation, and has been with the company ever since.

D. P. Fullerton, Jr. (A'29) who was in charge of the Bell System exhibit at the 1940 New York World's Fair, has been appointed engineer of buildings and equipment, Long Island area, New York Telephone Company, New York, N. Y.

National Defense Appointments

The following members of the Institute are among those who have received recently appointments to the United States Army, Navy, or Air Corps, in most cases in connection with the national defense program.

G. F. Tinkler (A'36) junior valuation engineer, State of California, Sacramento, is now lieutenant, United States Army, Fort McQuaid, Watsonville, Calif. **G. D. Burton** (A'39) meter tester Idaho Power Company, Pocatello Falls, is now junior electrical engineer, Navy Bureau of Ordnance, Washington, D. C. **B. F. Meador** (A'29, M'35) electrical engineer, Black and Veatch, Kansas City, Mo., is now major in the field artillery reserve, United States Army, St. Louis, Mo. **J. F. Sodaro** (A'39) partner, Sodaro Manufacturing Company, Chicago, Ill., is now an aviation cadet, United States Naval Air Station, Pensacola, Fla. **J. E. Breth** (A'38) assistant electrical engineer, Consolidation Coal Company, Inc., Fairmont, W. Va., is now major, Office of the Quartermaster General, War Department, Washington, D. C. **H. C. Brown** (A'39) Joseph T. Ryerson and Son, St. Louis, Mo., and **R. A. Greulich** (A'37) transmission man, Pacific Telephone and Telegraph Company, Reno, Nev., are now at Fort Winfield Scott, San Francisco, Calif. **Chandler Stewart, Jr.** (A'40) is now employed as junior radio engineer, Navy Department, Vallejo, Calif. **F. P. Quigley** (M'33) power division, Public Works Administration, Washington, D. C., is now lieutenant commander, United States Naval Reserve, Bureau of Ships, Navy Department, Washington. **J. F. Marotta** (A'40) who enlisted in the United States Army Signal Corps in December 1939, is now corporal, 311th Signal Aviation Company, Hamilton Field, Calif. **W. K. St. Clair** (A'22, M'28) equipment engineering department, Bell Telephone Laboratories, New York, N. Y., is now at the United States Army Corps Area Signal Office, Governors Island, N. Y. **N. J. Bukey** (A'31, M'38) supervisor, cable construction department, Cincinnati (Ohio) Gas and Electric Company, is now captain, Coast Artillery, Fort Monroe, Va.

Obituary • • •

Lewis Buckley Stillwell (A'92, M'92, F'12) consulting engineer, Princeton, N. J., died January 19, 1941, at Baltimore, Md. He was a past president of the Institute (1909-10), recipient of the Lamme and Edison medals and of various other awards, and one of the outstanding pioneers in high-voltage transmission. A complete biographical sketch will appear in the March issue.

Leo Alonzo Phillips (A'94, M'11, F'13) retired consulting engineer, New Orleans, La., died December 9, 1940, at Montgomery, Ala. He was born September 8, 1872, at New Orleans, La., and educated there. After a year as apprentice with the Louisiana Electric Light and Power Company, New Orleans, he entered the Edison Machine Works, Schenectady, N. Y. (a predecessor of the General Electric Company), as a student in 1889. In 1892 he went with the Edison Electric Illuminating Company of New York, N. Y., and in 1893 was employed by the Westinghouse Electric and Manufacturing Company as a student at the Newark, N. J., shops, later being transferred to East Pittsburgh, Pa. From 1897 to 1900 he was superintendent of the Flushing, N. Y., plant of the New York and Queens Light and Power Company. During 1900 he was in charge of the installation and operation of the substation at the Paris Exposition, for the French Westinghouse Company, Paris. He was employed successively by the Trade Dollar Consolidated Mining Company of Pittsburgh, Pa., at its power plant at Snake River, Idaho; as electrical engineer for the consulting firm of Sanderson and Porter, New York, N. Y.; and in the Pittsburgh sales office of the Westinghouse company before becoming sales engineer for the Allis-Chalmers Manufacturing Company, at Pittsburgh in 1908. In 1910 he was transferred to Milwaukee, Wis., as assistant chief engineer, later becoming special engineer. He went into the steam and electrical equipment business in New York, N. Y., about 1916. Some ten years later he became consulting engineer for the Pittsburgh Vetagrande Mining Company, Zacatecas, Mexico, a year later becoming vice-president and chief engineer of the Federal Water Service Corporation, New York, N. Y., and later chief engineer for Charles A. Smith and Company, Engineers, New York. He engaged in consulting engineering practice in Brooklyn, N. Y., for about five years before his recent retirement.

Lewis Degen (A'95, M'13) retired consulting electrical signal engineer, Burlingame, Calif., died December 22, 1940. He was born November 20, 1862, at Ottawa, Ill., and educated there. He began his career in 1888 as a partner in the firm of Armstrong and Degen, constructing electrical engineers, Englewood, Ill. The following year he was responsible for constructing the lighting systems for the towns of Marseilles and Ottawa, Ill., and later he became superintendent of the Illinois Electric Light and Power Company. Turning to electric street railway construction, he worked as erecting and superintending engineer in Joliet and Ottawa, Ill., San Jose, Calif., and Denver, Colo. In 1892 he joined the Thomson Houston International Electric Company and was sent to Rio de Janeiro, Brazil, where he installed the electric street railway system. He became constructing electrical engineer for the Sao Paulo, Brazil, Tramway, Light, and Power Company about ten years later. He remained in Brazil as a construction engineer until 1913, when he returned to the United States, settling at Long Beach, Calif. Later he went to Pasadena, Calif., where he installed the city's fire alarm system. In

1920 he became electrical engineer for the Pacific Fire Extinguisher Company, San Francisco, Calif., and in 1923 consulting electrical signal engineer for the City of Los Angeles, Calif. He later extended his consulting practice to other cities and was active in it until 1940.

Ernest Ingalls Dyer (A'99) consulting engineer, Piedmont, Calif., died February 4, 1939, according to information just received. He was born at Alvarado, Calif., September 4, 1872, and was graduated from the College of Mechanics of the University of California in 1894, afterward taking a year's graduate work in electrical engineering. He was employed by the San Joaquin (Calif.) Electric Company for a short time, before being employed in 1897 as engineer and manager of the engineering department of the American Trading Company, at Yokohama, Japan, and Port Arthur, Manchuria. From 1904 to 1909 he was manager in Seattle, Wash., for Charles G. Moore and Company, Engineers, and the Babcock and Wilcox Company. From 1909 to 1925 he was associated with the Union Oil Company of California, first as engineer in the manufacturing department, becoming engineer in chief and manager of that department, and later technical director of the company and a member of the board of directors and the executive committee. He was also a director and technical engineer for the Union Oil Company of Canada, 1920-24. Since 1924 he had been president of the Dyer Estate Company. He had retired from active engineering practice. He was the author of several inventions.

Fulgencio Archila (A'29) assistant engineer, Interborough Rapid Transit Company, New York, N. Y., died December 3, 1940. He was born October 13, 1891, at Sogamoso, Colombia, and was graduated in 1912 from the Escuela de Mecanica, Bogota, Colombia, and received the degree of electrical engineer in 1916 from the Instituto Tecnico Superiore, Milan, Italy. From 1916 to 1919 he was an assistant electrical engineer with Pirelli and Company, Milan. For the next four years he was engineer of electrical and mechanical construction, General Engineering Works, Bogota, and at the same time professor of electricity at the Universidad Colombiana de Ingenieros, Bogota. He came to the United States in 1923 and the following year was employed as electrical draftsman in the office of the chief engineer, Interborough Rapid Transit Company, later becoming engineer in the chief engineer's office, and recently assistant engineer of the company.

Adolph H. Rapport (A'30, M'40) instructor in electrical engineering, College of the City of New York, New York, N. Y., died December 17, 1940. He was born at New York February 8, 1908, and received the degrees of bachelor of science, 1927, and electrical engineer, 1928, from the College of the City of New York, and that of master of arts from Columbia University in 1938. He was employed by the New York Edison Company 1928-35, first for a training period in the distribu-

tion department, then as safety inspector, and from 1931 as junior engineer in the test bureau. Beginning in 1930 he was an instructor in electrical engineering at the evening sessions of the College of the City of New York, and since 1935 had been a full-time instructor in the day courses. He also had taught evening courses for the New York Edison and Consolidated Gas companies.

Henry M. Bostwick (A'21) director of lamp sales, Canadian Westinghouse Company, Ltd., Hamilton, Ont., Canada, died November 25, 1940. He was born at Ithaca, N. Y., December 6, 1877, and received the degree of mechanical engineer from Cornell University in 1901. He was employed by the Westinghouse Electric and Manufacturing Company at East Pittsburgh, Pa., in the same year, and in 1903 was transferred to the East Pittsburgh office of Canadian Westinghouse. He was sent to Hamilton in 1906, becoming assistant manager of sales in 1909, and manager of sales in 1919. He held the latter position until 1939, when he became director of lamp sales.

Richard Oscar Nixon (A'22) superintendent of power, Philadelphia Rapid Transit Company, Philadelphia, Pa., died December 25, 1940. Born July 17, 1883, at Philadelphia, he received a certificate in electrical engineering from Drexel Institute in 1913, and continued graduate study at that institution afterward. From 1902 to 1904 he was a switchboard operator for the Philadelphia Electric Company. He went with the Philadelphia Rapid Transit Company in the same capacity in 1904, becoming system operator in 1913, engineering assistant in 1918, and superintendent of power about five years later.

Reginald Morley Prowse (A'39) assistant electrical engineer, Tata Iron and Steel Company, Ltd., Jamshedpur, India, died February 11, 1940. He was born December 24, 1905, at Torquay, England, and received the diploma of Faraday House in 1929. From 1930 to 1934 he was special representative in India for Westinghouse Electric International Company, and from 1935 to 1938 manager for India of Westinghouse Electric Company of India, Ltd. He had been with the Tata Iron and Steel Company since 1938. He was also a member of the Institution of Electrical Engineers of Great Britain.

Membership • •

Recommended for Transfer

The board of examiners, at its meeting on January 23, 1941, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the national secretary.

To Grade of Member

Chanon, H. J., electrical engineer, General Electric Company, Cleveland, Ohio.
Dean, S. M., chief assistant superintendent of electrical system, The Detroit Edison Company, Detroit, Mich.

Gruenberg, G. S., inspector of electrical engineering materials, U. S. Navy Department, Camden, N. J.
Hayward, C. D., relay development engineer, General Electric Company, Philadelphia, Pa.
Hoadley, H. E., chief distribution engineer, The Empire District Electric Company, Joplin, Mo.
McIlvaine, W. D., assistant engineer, Minneapolis-St. Paul Sanitary District, St. Paul, Minn.
Merriman, J. H., maintenance engineer, Northern States Power Company, Minneapolis, Minn.
Patterson, L. R., planning engineer, Public Service Company of Colorado, Denver, Colo.
Russell, J. B., assistant professor of electrical engineering, Columbia University, New York, N. Y.
Schuck, O. H., electrical engineer, C. G. Conn, Ltd., Elkhart, Ind.
Schultz, S. E., chief engineer, Bonneville Power Administration, Portland, Ore.
Thorson, W. R., general manager, Municipal Water and Light Plants, Muscatine, Iowa.
Wheeler, R. C. H., associate professor of electrical engineering, Postgraduate School, United States Naval Academy, Annapolis, Md.
Wilcox, S. C., electrical engineer, County Engineers Office—Cuyahoga, Cleveland, Ohio.
Yagodkin, V. K., electrical engineer, Tennessee Valley Authority, Knoxville, Tenn.

15 to Grade of Member

Applications for Election

Applications have been received at headquarters from the following candidates for election to membership in the Institute. Names of applicants in the United States and Canada are arranged by geographical Districts. If the applicant has applied for direct admission to a grade higher than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the national secretary before February 28, 1941, or April 30, 1941 if the applicant resides outside of the United States or Canada.

United States and Canada

1. NORTH EASTERN

Andrias, J., Stone and Webster Engineering Corporation, Boston, Mass.
Borst, D. W., General Electric Company, Schenectady, N. Y.
Bowman, J. Y., General Electric Company, Schenectady, N. Y.
Bush, J. K., General Electric Company, Pittsfield, Mass.
Chin, P., General Electric Company, Schenectady, N. Y.
Deines, E. W., Jr., Narragansett Electric Company, Providence, R. I.
Dykstra, L. J., Victor Insulators, Incorporated, Victor, N. Y.
England, W. H., General Electric Company, West Lynn, Mass.
Frost, G. E., General Electric Company, Schenectady, N. Y.
Gara, W. B., United States Army Engineers, Fort Devens, Mass.
Graham, R. C., General Cable Corporation, Rome, N. Y.
Hart, J. L., General Electric Company, Schenectady, N. Y.
Hayes, T. B., Jackson and Moreland, Boston, Mass.
Lawry, C. C., Jr., General Electric Company, Schenectady, N. Y.
Lederer, E. H., General Electric Company, Schenectady, N. Y.
Lloyd, S. C., Jr., Remington Arms Company, Bridgeport, Conn.
McDorman, J. A., Jr., Allis-Chalmers Manufacturing Company, Boston, Mass.
Meyers, N. H., General Electric Company, Schenectady, N. Y.
Price, J. C., General Electric Company, Schenectady, N. Y.
Putnam, G. R., Chase Brass and Copper Company, Incorporated, Waterbury, Conn.
Rosenthal, E. M., Curtiss-Wright Corporation, Buffalo, N. Y.
Shepard, B. R., General Electric Company, Lynn, Mass.
Stowell, C. F., Corps of Engineers, United States Army, South Schenectady, N. Y.
Thiessen, A. E. (Member), General Radio Company, Cambridge, Mass.
West, E. S., Hygrade Sylvania Corporation, Salem, Massachusetts.
Wolfner, W. F., II., Photoswitch Incorporated, Cambridge, Mass.

2. MIDDLE EASTERN

Albright, W. D., Westinghouse Electric and Manufacturing Company, Sharon, Pa.
Bartlett, P., General Electric Company, West Philadelphia, Pa.
Berkley, L. H., Federal Power Commission, Washington, D. C.
Beyer, F. W., Autocall Company, Shelby, Ohio.
Biester, W. H., Jr., Electro Construction Company, Philadelphia, Pa.
Bleazey, J. C., General Motors Corporation, West Trenton, N. J.
Bradley, R., VI., Consolidated Gas, Electric Light and Power Company, Baltimore, Md.

Christy, H. A. (Member), National Youth Administration, Philadelphia, Pa.
 Collis, H. O., Owens-Corning Fiberglass Corporation, Newark, Ohio.
 Colman, C. W., Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.
 Crockett, E. G., 412 Morris Building, Philadelphia, Pa.
 Dorn, W. C., Bra Bon Electric Company, Philadelphia, Pa.
 Dralle, H. E., Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.
 Dunlap, H. B., Cincinnati Gas and Electric Company, Cincinnati, Ohio.
 Edkins, E. V. (Member), Atlantic Refining Company, Philadelphia, Pa.
 Elliott, C. L., Bureau of Aeronautics, Navy Department, Washington, D. C.
 Elvove, E., Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.
 Fields, C. V., Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.
 Fisher, R. E., Consolidated Gas, Electric Light and Power Company, Baltimore, Md.
 Frankenfeld, A. W. (Member), E. I. du Pont de Nemours Company, Incorporated, Wilmington, Delaware.
 Frazee, F. W., Westinghouse Electric and Manufacturing Company, Sharon, Pa.
 Getaz, J. L., Jr., Ingersoll-Rand Company, Phillipsburg, N. J.
 Haberland, E. R., United States Navy Yard, Washington, D. C.
 Hazen, D. F., Jr., Western Union Telegraph Company, Cincinnati, Ohio.
 Herr, D. L., United States Navy, Washington, D. C.
 Hines, C. M., Westinghouse Airbrake Company, Wilmerding, Pa.
 Hoebel, H. F., The Toledo Edison Company, Toledo, Ohio.
 Hudson, B. T., Carnegie-Illinois Steel Corp., Pittsburgh, Pa.
 Hulse, E. H., Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.
 Kendall, P. R., Kendall Radio Company, Cleveland, Ohio.
 Klar, R. L., Jr., Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.
 Kovski, J. J., Aircraft Radio Laboratory, Wright Field, Dayton, Ohio.
 Kozak, T. J., Toledo Edison Company, Toledo, Ohio.
 Marras, A. W., The Babcock and Wilcox Company, Akron, Ohio.
 Miller, R. L., Westinghouse Electric and Manufacturing Company, Sharon, Pa.
 Moe, W. J., Rural Electrification Administration, Washington, D. C.
 Muckey, M., Federal Machine and Welder Company, Warren, Ohio.
 Neily, J. W., Robbins and Myers, Incorporated, Springfield, Ohio.
 Nelson, E. N. (Member), Ohio Public Service Company, Ashland, Ohio.
 Ogle, F. M., Trumbull Electric Manufacturing Company, Philadelphia, Pa.
 Packard, C. A., Struthers Dunn, Incorporated, Philadelphia, Pa.
 Paulson, A. W., New York Shipbuilding Corporation, Camden, N. J.
 Ponkow, J. E., Westinghouse Electric and Manufacturing Company, Pittsburgh, Pa.
 Pruitt, G. M., Jr., New York Shipbuilding Corporation, Camden, N. J.
 Roberts, C. B., Philadelphia Electric Company, Philadelphia, Pa.
 Ruhl, F. L., United States Navy Yard, Philadelphia, Pa.
 Sherman, W. A., Duquesne Light Company, Pittsburgh, Pa.
 Smitheman, E. W., 3rd, United States Navy Yard, Philadelphia, Pa.
 Snyder, A. E., Jr., Appalachian Electric Power Company, Charleston, W. Va.
 Sprowl, P. R., Westinghouse Electric and Manufacturing Company, Sharon, Pa.
 Steelman, A. T., Jr., Bell Telephone Company of Pennsylvania, Philadelphia, Pa.
 Thompson, C. E., Thompson Company, Philadelphia, Pa.
 Viebahn, W. W., Westinghouse Electric and Manufacturing Company, Pittsburgh, Pa.
 Wagner, R. B., Chesapeake and Potomac Telephone Company, Washington, D. C.
 Wright, L. L., Westinghouse Electric and Manufacturing Company, Sharon, Pa.

3. NEW YORK CITY
 Bates, A. A., New York and Queens Electric Light and Power Company, Flushing, N. Y.
 Bowen, J. J., General Electric Company, New York, N. Y.
 Bower, J., Consolidated Edison Company, New York, N. Y.
 Bremer, F. V., WAAT Bremer Broadcasting Corporation, Jersey City, N. J.
 Bull, R. H., Long Island Lighting Company, Glenwood Landing, N. Y.
 Carty, J. P., Western Union Telegraph Company, New York, N. Y.
 Dench, E. C., Interchemical Corporation, New York, N. Y.
 Dubbs, W. P., Westinghouse Electric and Manufacturing Company, New York, N. Y.
 Durfee, G. I., Westinghouse Electric and Manufacturing Company, New York, N. Y.
 Evans, L. S., Consolidated Edison Company of New York, Incorporated, New York, N. Y.
 Floyd, J. H., Westinghouse Electric and Manufacturing Company, Newark, N. J.

Fragola, C. F., Sperry Gyroscope Company, Garden City, L. I., N. Y.
 Galbraith, S. L., Western Electric Company, Kearny, N. J.
 Hatch, B. G., General Electric Company, New York, N. Y.
 Hodges, H. L., Jr. (Member), New York and Queens Electric Light and Power Company, Flushing, N. Y.
 Ibat, R. M., United States Signal Corps, Brooklyn, N. Y.
 Joecks, A. K., Consolidated Edison Company of New York, Incorporated, New York City, N. Y.
 King, H. T., Bell Telephone Laboratories, Incorporated, New York, N. Y.
 Krueger, A. M., Ward Leonard Electric Company, Mt. Vernon, N. Y.
 Lane, H. A., New York and Queens Electric Light and Power Company, Flushing, N. Y.
 LeClair, W. E., Standard Coated Products Corporation, Buchanan, N. Y.
 Lee, L. Y., Aircraft Radio Corporation, Boonton, N. J.
 Mallinckrodt, C. O., Bell Telephone Laboratories, Incorporated, New York, N. Y.
 Milton, L., Solar Manufacturing Corporation, Bayonne, N. J.
 Nagy, A. W., Columbia University, New York, N. Y.
 Nissley, R. R., Westinghouse Electric and Manufacturing Company, New York, N. Y.
 Patterson, H. R., War Department, New York Signal Corps, Brooklyn, N. Y.
 Rae, G. G., Holophone Company, Incorporated, New York, N. Y.
 Rappaport, G., 92 Cook Street, Brooklyn, N. Y.
 Rebori, M. J., Consolidated Edison Company of New York, Incorporated, New York, N. Y.
 Rheame, R. H., Western Electric Company, Incorporated, Kearny, N. J.
 Roehm, F. J., War Department, New York Signal Corps, Brooklyn, New York.
 Schimpf, L. G., Bell Telephone Laboratories, Incorporated, New York, N. Y.
 Schramm, C. W. (Member), Bell Telephone Laboratories, Incorporated, New York, N. Y.
 Sherman, H., War Department, New York Signal Corps, Brooklyn, N. Y.
 Suski, H. M., Western Electric Company, Kearny, N. J.
 Wessely, G., Consolidated Edison Company of New York, Incorporated, New York, N. Y.
 Wilcox, J. L., Western Union Telegraph Company, New York, N. Y.
 Williams, H. B. (Member), Columbia University, New York, N. Y.
 Wright, R. R., New York University, New York, N. Y.

4. SOUTHERN
 Beatty, P. B., Western Union Telegraph Company, Charlotte, N. Car.
 Harder, R. N., Aluminum Company of America, Alcoa, Tenn.
 Harrison, A. E., United States Army, Fort Jackson, S. Car.
 Hollandsworth, F. M., Memphis Light, Gas and Water Division, Memphis, Tennessee.
 Jones, L. F., The Little Ocmulgee Electric Membership Corporation, Alamo, Ga.
 Klein, H., National Advisory Council for Aeronautics, Langley Field, Virginia.
 Lawson, H. L., Memphis Light, Gas and Water Division, Memphis, Tenn.
 McGillivray, A., Tennessee Valley Authority, Wilson Dam, Ala.
 Obrecht, R. G., Tennessee Valley Authority, Chattanooga, Tenn.
 Ostaff, W. A., Trumbull Electric Manufacturing Company, Ludlow, Ky.
 Stegner, A. L. (Member), Ray W. Chanaberry, Incorporated, Louisville, Ky.

5. GREAT LAKES
 Badgett, E. D., Granite City Steel Company, Granite City, Ill.
 Basic, E., Russell Electric Company, Chicago, Ill.
 Brokaw, R. T., Jr., Barnes Drill Company, Rockford, Ill.
 Carlson, McK. S. (Member), Commonwealth Edison Company, Chicago, Ill.
 DeBoer, H. H., Michigan Bell Telephone Company, Detroit, Mich.
 Findley, R. L. (Member), Westinghouse Electric and Manufacturing Company, Detroit, Michigan.
 Gable, J. G., Cutler-Hammer, Incorporated, Milwaukee, Wisconsin.
 Gollin, N. W., 1218 Washtenaw, Ann Arbor, Mich.
 Gossman, L. Z., General Electric Company, Fort Wayne, Ind.
 Gray, A. S., Insulation Manufacturers Corporation, Chicago, Ill.
 Hird, F. S., Northwestern Bell Telephone Company, Davenport, Iowa.
 Jones, D. L., Automatic Electric Company, Chicago, Ill.
 Kieb, N. A. (Member), Albert Kahn Incorporated, Detroit, Michigan.
 Latta, H. A., Howell Electric Motors Company, Battle Creek, Michigan.
 Little, G. W., Chrysler Corporation, Detroit, Michigan.
 Lueders, B. C., Prairie Du Sac, Wisconsin.
 MacKinnon, R. H., Public Service Company of Northern Illinois, Evanston, Ill.
 Matsch, L. W. (Member), Commonwealth Edison Company, Chicago, Ill.

McNamara, B. F., Insulation Manufacturers Corporation, Chicago, Ill.
 Oman, H., Allis-Chalmers Manufacturing Company, Milwaukee, Wis.
 Lambert, R. H., Allis-Chalmers Manufacturing Company, West Allis, Wis.
 Petersen, F. H., Commonwealth Edison Company, Chicago, Ill.
 Petersen, H. A., Allis-Chalmers Manufacturing Company, Milwaukee, Wis.
 Refer, L. W., Carnegie-Illinois Steel Corporation, Chicago, Ill.
 Rice, D. N., Harnischfeger Corporation, Milwaukee, Wisconsin.
 Rieke, C. R. (Member), Commonwealth Edison Company, Chicago, Ill.
 Sagendorph, A. L. (Member), Commonwealth Edison Company, Chicago, Illinois.
 Stone, C. B., Stone, Stafford, and Stone, Indianapolis, Indiana.
 Swanson, A. R., General Electric X-ray Corporation, Chicago, Ill.
 Swenson, L. M., Allis-Chalmers Manufacturing Company, Milwaukee, Wis.
 Taylor, D. W., Public Service Company of Northern Illinois, Evanston, Ill.
 Tolentino, J. G., Electrical Engineers Equipment Company, Melrose Park, Illinois.
 Webb, H. E., Jr., Chrysler Corporation, Highland Park, Michigan.
 Weston, A. H., Chicago District Electric Generating Corporation, Hammond, Indiana.
 Wold, E. A., Western Union Telegraph Company, Minneapolis, Minn.

6. NORTH CENTRAL
 Paynter, T. E., Colorado School of Mines, Golden, Colo.
 Sheldon, M. T., Central Electric and Telephone Company, Woonsocket, So. Dakota.

7. SOUTH WEST
 Boyer, O. A., Western Union Telegraph Company, Sweetwater, Texas.
 Brown, R. E., Southwestern Bell Telephone Company, Oklahoma City, Okla.
 Fairchild, R. J., A. Y. Taylor and Company, Clayton, Mo.
 Fryer, R. T., Westinghouse Electric and Manufacturing Company, St. Louis, Mo.
 Garlow, G. D., Southwestern Bell Telephone Company, Oklahoma City, Okla.
 Halferty, C. W., Kansas Gas and Electric Company, Wichita, Kans.
 Jenner, J. W., Shelley Electric Company, Wichita, Kans.
 King, D. E., Oklahoma Power and Water Company, Sand Springs, Okla.
 Lebens, J. C., Jr., Bussmann Manufacturing Company, St. Louis, Mo.
 McNicol, J. E., Kansas Gas and Electric Company, Wichita, Kans.
 Pitts, A. E., Oklahoma Gas and Electric Company, Ardmore, Okla.
 Ross, L. L., Kansas Gas and Electric Company, Wichita, Kans.
 Roush, G. E., United States Army, Signal Corps, Fort Riley, Kans.
 Scott, R. B., General Electric Company, Kansas City, Mo.
 Spehr, C. J., 218 East Fifth Street, Hoisington, Kans.
 Weckel, M. F., Kansas Gas and Electric Company, Wichita, Kans.
 Wilkins, J. D., White-Rodgers Electric Company, St. Louis, Mo.

8. PACIFIC
 Bonner, H. W., Victor Equipment Company, San Francisco, Calif.
 Janssen, R. R., North American Aviation, Incorporated, Inglewood, Calif.
 Jordan, H., Trumbull Manufacturing Company, Los Angeles, Calif.
 Mirk, A., Bethlehem Steel Company, San Francisco, California.
 Strum, F. L., United States Army, Fort Baker, Calif.
 Varney, B. F., North American Aviation, Incorporated, Inglewood, Calif.

9. NORTH WEST
 Anderson, J. W., Bonneville Power Administration, Portland, Ore.
 Carlstad, A., Public Utility District No. 1, Wahkiakum County, Cathlamet, Wash.
 Dean, R. V., Mountain States Telephone and Telegraph Company, Helena, Mont.
 Lycksell, J. M., Puget Sound Navy Yard, Bremerton, Wash.
 McConnell, G. B., Mountain States Telephone and Telegraph Company, Boise, Idaho.

10. CANADA
 Brace, G. A. (Member), Ferranti Electric Limited, Toronto, Ont.
 Kirkland, W. D., Hydro Electric Power Commission, Toronto, Ont.
 Knudsen, P. D., Imperial Oil Limited, Toronto, Ont.
 Turnbull, A. G. (Member), Canadian General Electric Company, Toronto, Ont.

Total, United States and Canada, 201

Elsewhere
 Lythall, R. T., Johnson and Phillips, Limited, London, S.E. 7, England.
 Total, elsewhere, 1

Of Current Interest

Concerning National Defense

The following news items, relating to various aspects of national defense activity, are grouped here for convenience.

WESTINGHOUSE REPORTS DEFENSE PRODUCTION

National defense accounted directly or indirectly for more than 40 per cent of the estimated \$390,000,000 worth of new business done by the Westinghouse Electric and Manufacturing Company in 1940, according to a year-end summary issued by the company. About \$23,000,000 was authorized for expansion of plant and equipment during the year, with \$9,000,000 more authorized for 1941. Employment increased from 49,519 to more than 56,000 in 1940. Principal expansions of Westinghouse facilities for defense purposes occurred at the steam division, South Philadelphia, Pa., which manufactures propulsion equipment for the United States Navy; at the radio division, Baltimore, Md., to increase production of radio equipment for Government orders; and at the lighting division, Cleveland, Ohio, to increase output of lighting and electrostatic air cleaning equipment for industries in defense production as well as for Government requirements. In addition, the company is constructing a \$5,000,000 gun equipment plant near Louisville, Ky., which it will build and operate for the Navy under a leasing arrangement.

TOOL ENGINEERS CO-OPERATE

Needs in all branches of the defense program will be emphasized at the forthcoming Machine Tool and Progress Exhibition, to be held at Detroit, Mich., March 25-29, 1941, in connection with the annual convention of the American Society of Tool Engineers. A special aeronautical exhibition and technical session are included. The theme of the convention is to be "education for national defense," with special consideration of the problem of securing skilled labor.

Local chapters of the ASTE are organizing educational committees to co-operate with manufacturing plants and schools in their areas in training apprentice mechanics, particularly for defense jobs, the society has announced.

HOUSING AND DEFENSE

That the private building industry has the capacity to provide most of the housing needs of the defense program, but that an immediate plan of action is essential, were basic findings of a survey "Housing for Defense," made by Miles L. Colean for the Twentieth Century Fund, and published November 8, 1940. The report recommended that Government policy encourage private building effort, entering into direct housing operation only on good evidence that private means cannot meet the need, but warned that some such situa-

tions will occur. It recommended extension of financing facilities by the Government. The survey showed the great need to be for low-cost housing, and recommended permanent, rather than temporary construction to meet the need. With a plan for coordinating housing with the defense program, emphasizing selective location for defense industries, many of the mistakes and delays which seriously impaired defense efforts during the World War could be avoided, the report declared.

DEFENSE AND EMPLOYMENT

Factory employment in New York State during November 1940 rose above 1929 levels for the first time, according to the preliminary 1940 report of the state labor department. Placements during the first nine months of 1940 showed a gain of 58 per cent over 1939 for all private industry; of more than 100 per cent for factory employment. Reflecting defense activity, the greatest demand is for skilled workers. Training programs are being set up in which vocational schools and factories are participating. The state employment service endeavors to meet the demand, not only by classifying workers' skills, but by asking employers to anticipate their labor needs, and if a shortage exists, recruiting workers for training.

Positions to Be Filled Through Civil Service Examination

Notice of the following positions, which will be filled through civil service examinations, is published here as a service to members of the Institute. Application forms and full information as to requirements for examinations may be obtained from the secretary of the Board of United States Civil Service Examiners at any first- or second-class post office, or from the United States Civil Service Commission, Washington, D. C.

Engineering draftsmen. Salaries range from \$1,620 to \$2,600 a year, less 3 1/2 per cent retirement deduction. Applicants may qualify in architectural, civil, electrical, heating and ventilating, lithographic, mechanical, plumbing, radio, structural, topographic, and other branches, except aeronautical, ordnance, or ship, which are covered by a previously announced examination. High-school education except for substituted drafting experience is required. Applicants must also show paid drafting-room experience, or completion of drafting course in a school specializing in drafting, or college engineering or architectural study; also experience in the branch chosen. Completion of advanced engineering or architectural study may be substituted for part of drafting training or experience. Written test not required; applicants will be rated on applications and corroborative evidence. Applications will be accepted until December 31, 1941.

Metallurgists and metallurgical engineers, various grades. For positions in the United States Bureau of Mines in connection with the national defense program for development of strategic metals. Salaries range from \$3,200 to \$5,600 a year, less 3 1/2 per cent retirement deduction. Applicants must have completed a four-year college course

with major study in chemistry, geology, mining, physics, engineering, or metallurgy, and have had responsible experience in metallurgy or metallurgical engineering. For the associate grade graduate study of specific value in the branch in which the applicant wishes to be rated may be substituted for the entire experience requirement; for the other grades a partial substitution may be made. No written test will be given. Applicants must not have passed their 60th birthday on the date of receipt of application.

Welding Research Committee Report

The welding research committee of Engineering Foundation has issued its annual report for 1940, in which are summarized the activities and achievements of its various divisions for the year. The report was published as a supplement to the *Journal* of the American Welding Society for December 1940.

The welding research committee was organized by Foundation in 1935, and its work has been sponsored jointly by the American Welding Society and the AIEE for the purpose of "assembling, digesting, and publishing all available information regarding welding research; stimulating and conducting needed research in the welding field; and correlating existing and future programs of welding research." Its activities have been conducted by three divisions: literature, fundamental research, and industrial research. C. A. Adams (A'94, F'13) consulting engineer of the E. G. Budd Manufacturing Company, Philadelphia, Pa., and a past president of the AIEE, is chairman of the committee; H. C. Boardman, director of research of the Chicago Bridge and Iron Company, Chicago, Ill., is vice-chairman; and W. Spraragen (A'17, M'26) technical secretary and editor of the *American Welding Society*, New York, N. Y., is executive secretary. Outstanding in the accomplishments of the committee during the year was the broadening of the base of support for its work. In 1939 the number of subscribing organizations and companies was 37; during 1940 the number increased to 63.

The work of the literature division consists of the preparation of reviews of welding literature, and during 1940 10 new reviews were published, bringing the total number published to 46. Several additional reviews are nearing completion. The more important reviews published during the year dealt with: welding of special metals; effect of certain ingredients in steel on the weldability; oxygen cutting of steel and oxygen-cutting procedure; flame cutting of non-ferrous metals; resistance welding of aluminum and its alloys; welding magnesium and its alloys; and welding nickel and its alloys.

Activities of the fundamental research division are concerned primarily with broadening the knowledge of the fundamental factors controlling welding processes and governing welding applications. Research grants from funds of the division were made

to five universities; three of these were for work on resistance welding.

The basic philosophy of the industrial research division is "to stimulate needed research by governmental departments and corporations, and to initiate, organize, and carry out co-operative research projects." These projects are divided into two general types: those relating to materials, and those dealing with specific subjects of broad general interest and importance. During 1940, work was progressing on 12 projects, each under jurisdiction of a separate committee. Outstanding accomplishments of this division during the year consisted of the financing of three large research projects dealing with: the weldability of steels and the effect of carbon manganese on weldability; structural welding research; and resistance (aeronautical) research.

Industry • • • •

Revere Award Announced for Workmen's Defense Ideas

Ten awards totaling \$10,000 have been offered by Revere Copper and Brass Incorporated for the ten best suggestions for speeding national defense submitted by workers in the American metal working industry. It is estimated that more than 2,000,000 foremen, subforemen, and workmen are eligible to compete for the awards, which range from a \$5,000 first prize to \$250. All ideas remain the property of the men who submit them, whether or not they win prizes. Awards will be made by a jury with the following members:

Henry Heald, president, Illinois Institute of Technology
Admiral Joseph Strauss, United States Navy, retired
Major General Frank Parker, United States Army, retired
Robert Watt, former American labor delegate to the International Labor Congress
C. Donald Dallas, president, Revere Brass and Copper Incorporated

Light as Sabotage Protection

The need of protection against sabotage, recognized by many privately owned utility and industrial plants, should not be ignored by municipally owned public services, according to A. F. Dickerson, manager, lighting division, General Electric Company, Schenectady, N. Y. He presents the following pointers on the use of protective lighting to avoid sabotage:

1. Plan protective lighting for the worst possible visibility conditions.
2. If there is glare, be sure it blinds the intruder, not the guards.
3. Do not create shadowed areas.
4. Put more light around the boundary of a property or at distant points if the guards are located in well-lighted areas.
5. Keep all backgrounds as light as possible; paint fences and buildings in light colors.
6. Plan area lighting so that some light is contributed to any one point from more than one source.

Early Home of GE Research Laboratory, Founded 40 Years Ago



THE General Electric Research Laboratory, 40th anniversary of which was commemorated at Schenectady, N. Y., December 17, 1940, occupied the building shown here early in 1901, after fire destroyed its first home in a barn at C. P. Steinmetz's residence. The laboratory now occupies two large buildings. It has had only two directors in its 40 years: Willis P. Whitney (A'01) now retired, and W. D. Coolidge (A'10, M'34), both AIEE Edison medalists. Speakers at the banquet celebrating the 40th anniversary of the laboratory's founding were Charles E. Wilson, president, General Electric Company; Doctor Karl T. Compton (F'31) president, Massachusetts Institute of Technology; and Samuel Ferguson (A'02) president, Hartford (Conn.) Electric Light Company, who was the first engineer of the laboratory.

7. Direct light across highways, streets, railroads, and navigable waterways so that glare or brightness will not prove a hazard to traffic.

8. Keep as much of the lighting equipment as possible well within the property.

Infrared Institute. The Fostoria Pressed Steel Corporation, Fostoria, Ohio, manufacturer of near-infrared equipment for baking, drying, dehydrating, and other operations, holds classes and laboratory demonstrations on the theory and practice of near-infrared applications, to provide accurate information for representatives of paint and enamel companies, conveyor makers, central station power salesmen, and others. Classes at the Near-Infrared Institute are held for two days each month and are open without charge to anyone interested.

Clean Air for Machines. Air from which more than 85 per cent of the dirt particles has been removed by 56 Precipitron cells is supplied to the newly installed Westinghouse 20,000-kva synchronous condenser of the Ohio Edison Company. This is reported to be the first application of electrostatic air cleaning to power-plant machinery.

H. L. Hibbard Dies. Harry Lyman Hibbard, retired manager of the marine department of Cutler-Hammer Manufacturing Company, died December 28, 1940, at Akron, Ohio. A native (1876) of Akron, he received the degree of mechanical engineer from Cornell University in 1899. He engaged in electrical work at the Newport

News (Va.) Shipbuilding and Drydock Company and for the Navy Department, Washington, D. C., before going with Cutler-Hammer in 1907 to organize its marine work. He continued with the company until his retirement in 1932. He became an Associate of the AIEE in 1907 and Fellow in 1921, and was active on the marine and standards committees, prior to his resignation in 1934.

GE Expands Plastics Department. General Electric Company has announced plans to expend approximately \$400,000 on expansion of the eastern facilities of the Plastics Department. A new building and added equipment at Pittsfield, Mass., will account for 75 per cent of the expenditure; the remainder will provide a new building and presses at Meriden, Conn., and installation of a new press at Lynn, Mass.

Education • • • •

Defense Courses Announced by Engineering Colleges

Approval of 444 engineering defense training courses, given by 91 engineering colleges in 44 states, the District of Columbia, and Puerto Rico, has been announced to date by the United States Office of Educa-

tion. These short intensive courses are financed under the \$9,000,000 program initiated in October 1940 (*EE*, Dec. '40, p. 521-2) to meet the shortage of engineers for service with the industries and government agencies engaged in national defense, the announcement states.

Acceptance of the proposals submitted by the individual colleges is based upon demonstration by the school that there is a definite defense need for the men to be trained, that it has the experience and facilities to give the instruction at reasonable cost, and that a sufficient number of qualified students are available, according to the United States Office of Education. Applicants are considered by the colleges individually; tuition for those accepted is paid by the Federal Government. While placement is not guaranteed, the fact that courses are aimed at recognized needs for specially trained personnel indicates that jobs will be available, the report states, pointing out that the United States Civil Service Commission, Federal and state employment services, and college placement bureaus will assist those completing the courses to find jobs.

Engineering Journalism at Cornell. A course in engineering journalism has been inaugurated at Cornell University to give technical instruction in editorial procedures and business methods to the staff of the *Cornell Engineer*. The section for editors will cover writing of technical articles, copy editing, proofreading, make-up and other procedures; that for members of the business staff will cover accounting, advertising, circulation problems, and other aspects of publication management. Staff members may take the course for two years, with a maximum of four hours credit.

NYU Teaches Research Laboratory Management. What is believed to be the first course in the United States in research laboratory management is being offered by New York University, beginning in February 1941. The rapid development of industrial research and its growing importance in the national defense program have produced a need for trained administrative personnel. The course is being planned in collaboration with an advisory committee headed by Maurice Holland (A'23, M'30) director of the division of engineering and industrial research, National Research Council.

More Jobs for Columbia Graduates. Positions offered men students graduating from Columbia University in 1940 showed an increase of 28 per cent over the preceding year, according to a recent report of the University appointments secretary. Nearly 100 per cent of the engineering, physics, and chemistry students were placed before commencement in 1940. The requirements of national defense, as well as increased recruiting by industrial companies, largely account for the gain, the report said.

High-Voltage Laboratory at Cornell. Construction of a new \$150,000 high-voltage laboratory for the Cornell University College of Engineering has been authorized by

the board of trustees of the University. The building, of steel construction, will be connected with a half-mile high-voltage transmission line. It will contain both 60-cycle and impulse-testing equipment, the former capable of providing 750,000 volts single phase or 433,000 volts three phase, and the latter capable of simulating lightning up to 3,000,000 volts. The laboratory will be used for research into the properties of air and other electrical insulating materials, and for testing apparatus for commercial purposes.

Honors • • • •

J. V. N. Dorr Receives Perkin Medal

The Perkin Medal, awarded annually for valuable work in applied chemistry, by the American section of the Society of Chemical Industry, has been conferred for 1940 upon Doctor J. V. N. Dorr, president, The Dorr Company, Inc. The award was made January 10, 1941, at a joint meeting with the American Chemical Society, American Institute of Chemical Engineers, Electrochemical Society, and Société de Chimie Industrielle.

Doctor Dorr is a native (1872) of Newark, N. J., and received the degree of bachelor of science from Rutgers University in 1894. He also has been awarded honorary degrees from that and other institutions. He spent some time as chemical experimenter in the laboratories of Thomas A. Edison, and was employed as assayer and chemist by several mining companies, before developing the group of important industrial inventions for which he is known. He organized The Dorr Company, of which he is president. He is a past president of United Engineering Trustees, Inc., and of the American Institute of Chemical Engineers, and has received the James Douglas Medal of the American Institute of Mining and Metallurgical Engineers, the Chemical Industry Medal, and one of the national "modern pioneer" awards of the National Association of Manufacturers.

Library • • • •

OPERATED jointly by the AIEE and the other founder societies, the Engineering Societies Library, 29 West 39th Street, New York, N. Y., offers a wide variety of services to members all over the world. Information about these services may be obtained on inquiry to the director.

Bibliography on Airplane Hangars

Current interest in all matters connected with aviation has prompted the Engineering Societies Library to prepare a list of references on the design and construction of airplane hangars. The list includes 100 articles selected from those published during the years 1928-40 in leading domestic and foreign periodicals, and contains material on both steel and reinforced-concrete structures.

Copies may be obtained by sending \$2 to Engineering Societies Library, 29 West 39th Street, New York, N. Y.

Other Societies •

AAAS Elects Langmuir

At the annual meeting of the American Association for the Advancement of Science, held at Philadelphia, Pa., December 27, 1940, to January 2, 1941, Doctor Irving Langmuir, research chemist, General Electric Company, Schenectady, N. Y., was elected president of the Association for the coming year. A native (1881) of Brooklyn, N. Y., Doctor Langmuir received the degrees of metallurgical engineer from Columbia University in 1903, and of master of arts and doctor of philosophy from the University of Gottingen in 1906, and has been awarded honorary doctor's degree by a number of institutions in the United States and other countries. He was an instructor in chemistry at Stevens Institute of Technology, Hoboken, N. J., before joining the General Electric Research Laboratory in 1909. Among his achievements are the development of the gas-filled tungsten lamp, electron discharge apparatus, the condensation high-vacuum pump, and atomic hydrogen welding. His honors include the Nobel Prize for chemistry (1932); the Hughes Medal of the Royal Society, London; the Rumford Medal, and many others. He is a member of many scientific and technical societies in the United States and in other countries.

ASA Reports 1940 Activities

Complete revision of the National Electrical Code was one of the important activities of the American Standards Association during 1940, as reported at its annual meeting December 11, 1940. (Details of the revised code appeared in "Some Notes of the National Electrical Code", by Alvah Small, *ELECTRICAL ENGINEERING*, December 1940, pages 503-04.) Revision of the National Electrical Safety Code is also under

Future Meetings of Other Societies

American Chemical Society. April 7-11, 1941, St. Louis, Mo.

American Institute of Chemical Engineers. Semi-annual meeting, May 19-21, 1941, Chicago, Ill.

American Institute of Mining and Metallurgical Engineers. Annual meeting, February 17-20, 1941, New York, N. Y.

American Physical Society. 240th meeting, February 21-22, 1941, Cambridge, Mass.

241st meeting, May 1-3, 1941, Washington, D. C.

American Railway Engineering Association. Annual meeting, March 11-13, 1941, Chicago, Ill.

American Society for Testing Materials. Spring meeting, March 3-7, 1941, Washington, D. C.

American Society of Civil Engineers. Spring meeting, April 23-25, 1941, Baltimore, Md.

American Society of Mechanical Engineers. Spring meeting, April 1-3, 1941, Atlanta, Ga.

Electrochemical Society. Spring meeting, April 16-19, 1941, Cleveland, Ohio.

Midwest Power Conference. April 9-10, 1941, Chicago, Ill.

National Electrical Manufacturers Association. February 17-21, 1941, Chicago, Ill.

May 11-15, 1941, Hot Springs, Va.

way, four sections having been redrafted during the past year.

Other ASA activities during 1940 included a new standard for rounding off numerical values, one completed standard for photographic equipment and progress on several others, a group of standards for gas appliances, further progress on prevention of occupational diseases and on standards for consumer goods, and authorization of four new safety projects. During the year 73 standards were approved.

Requirements of the national defense program are expected to cause emphasis on undertakings vital to defense and on related safety codes during the coming year according to Retiring President E. A. Prentiss.

R. F. Zimmerman, vice-president, United States Steel Corporation, and former vice-president, ASA, was elected president for

the coming year. R. P. Anderson, American Petroleum Institute, was re-elected chairman of the Standards Council, and H. S. Osborne (A'10, F'21), American Telephone and Telegraph Company, vice-chairman.

Chemical Society Acquires Building

The American Chemical Society has announced the purchase of a building at 16th and M Streets, NW, Washington, D. C., as national headquarters for the society. Rapid growth of the organization during 1940 is said to have rendered its present headquarters inadequate. The present membership is about 26,000 chemists and chemical engineers, according to the announcement.

transforms of any excitation voltages appearing in the mesh. The entire right-hand members are sometimes called the "loop excitation functions" to correspond with the self and mutual "loop impedance functions" which appear in the terms of the left-hand members of the equations.

Solving equations 3 and 4 gives

$$I_1(s) = \frac{(E+V)s^2 + \frac{i_0}{C}s + \frac{E}{LC}}{R\left(s^2 + \frac{1}{RC}s + \frac{1}{LC}\right)} \frac{1}{s} \quad (9)$$

$$I_2(s) = \frac{(E+V-Ri_0)s^2 + RVs}{R\left(s^2 + \frac{1}{RC}s + \frac{1}{LC}\right)} \frac{1}{s} \quad (10)$$

Here the factor $1/s$ is written separately to emphasize the similarity to the usual notation where the unit function 1 would appear. Direct application of the expansion theorem gives

$$i_1(t) = \frac{E}{R} + \frac{1}{R} e^{-\alpha t} \left[V \cos \omega t + \frac{Ri_0 - E - \frac{V}{2}}{C\omega} \sin \omega t \right] \quad (11)$$

$$i_2(t) = e^{-\alpha t} \left[\frac{E+V-Ri_0}{R} \cos \omega t + \frac{Ri_0 + V \left(\frac{2R^2C}{L} - 1 \right) - E}{2R^2C\omega} \sin \omega t \right] \quad (12)$$

in which

$$\alpha = \frac{1}{2RC}$$

and

$$\omega = \sqrt{\left(\frac{1}{LC}\right)^2 - \left(\frac{1}{2RC}\right)^2}$$

These are the expressions given by Meyerhoff and Reed except for the correction of the typographical error in their value of ω . (It will be noted that in figure 1 of their letter the arrow on V_e indicates the direction of voltage drop, while the arrow on E shows the direction of voltage rise.)

The Laplacian transform method possesses all the advantages of the Heaviside operational calculus and is in fact the same wherever the latter applies. The Laplacian method, however, allows a little more direct approach to certain problems, especially those involving initial conditions, excitation by voltages other than constant direct current applied at $t=0$, and impulsive responses. It is subject to no restrictions which do not apply also to the usual operational method and notation. A short review of the Laplacian transform method is given on page 2-108 of Eshbach's "Handbook of Engineering Fundamentals" (John Wiley, 1936) and a more complete summary and bibliography in a paper by M. G. Malti (EE, Nov. '35, p. 1222-7) and especially in the discussions thereof (EE, July '36, p. 826-30).

PAUL L. MORTON (A'33)

(Instructor in electrical engineering, University of California, Berkeley)

Letters to the Editor • • •

INSTITUTE members and subscribers are invited to contribute to these columns expressions of opinion dealing with published articles, technical papers, or other subjects of general professional interest. While endeavoring to publish as many letters as possible, Electrical Engineering reserves the right to publish them in whole or in part or to reject them entirely. Statements in letters are

expressly understood to be made by the writers; publication here in no wise constitutes endorsement or recognition by the AIEE. All letters submitted for publication should be typewritten, double-spaced, not carbon copies. Any illustrations should be submitted in duplicate, one copy an inked drawing without lettering, the other lettered. Captions should be supplied for all illustrations.

A Transformation Extending the Use of Heaviside's Operational Calculus

To the Editor:

Messrs. Meyerhoff and Reed (EE, Sept. '40, p. 385) have extended the use of Heaviside's operational calculus to circuits in which the initial currents and charges are not zero, by introducing new variables which satisfy the initial rest requirement, then solving the problem in terms of these new variables, and finally returning to the actual currents of the circuit. A more straightforward method is available, however, which also places no restriction upon the initial conditions, which somewhat reduces the algebra involved, and which avoids the introduction of fictitious currents and charges. In the Laplacian transform method the initial conditions are introduced when the operational equations are written, and direct application of the Heaviside expansion theorem gives the final solution.

This method would be applied to the circuit considered by Meyerhoff and Reed as follows (see figure 1): Let the initial voltage across the capacitor be V , with signs as shown, and the initial current in the coil be $i_0 = i_1(0) - i_2(0)$. The differential equations for the two meshes are:

$$\left(L \frac{d}{dt} + R\right) i_1(t) - L \frac{d}{dt} i_2(t) = E \quad (1)$$

$$-L \frac{d}{dt} i_1(t) + \left(L \frac{d}{dt} + \frac{1}{C} \int dt\right) i_2(t) = 0 \quad (2)$$

Using the Laplacian transformation the "operational" equations are

$$(Ls + R)I_1(s) - LsI_2(s) = \frac{E}{s} +$$

$$L[i_1(0) - i_2(0)] = \frac{E}{s} + Li_0 \quad (3)$$

$$-LsI_1(s) + \left(Ls + \frac{1}{Cs}\right)I_2(s) = \frac{V}{s} - Li_0 \quad (4)$$

in which the complex variable s appears in place of the operator p and the transform E/s in place of the step function $E1$. The initial conditions were automatically introduced in writing the transforms for the various terms, as follows:

$$\mathcal{L}[E1] = \frac{E}{s} \quad (5)$$

$$\mathcal{L}[i(t)] = I(s) \quad (6)$$

$$\mathcal{L}\left[L \frac{d}{dt} i(t)\right] = LsI(s) - Li(0) \quad (7)$$

$$\mathcal{L}\left[\frac{1}{C} \int i(t) dt\right] = \frac{1}{Cs} I(s) + \frac{q(0)}{Cs} = \frac{1}{Cs} I(s) - \frac{V(0)}{s} \quad (8)$$

Examination of equations 3 and 4 will show that they can be written directly from inspection of the circuit. The right-hand member of each is the sum of all the initial flux-linkages in the direction of the mesh current, plus $1/s$ times the sum of all the initial capacitor voltage rises, plus the

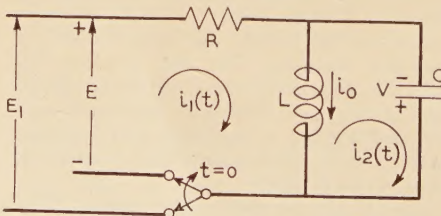


Figure 1

Hyperbolic Functions of Complex Variables

To the Editor:

Most students, and not a few mature engineers, are bothered by their inability to grasp the physical significance or geometric interpretation of the hyperbolic functions of complex variables that are encountered in transmission-line theory. Trigonometric and hyperbolic functions of real variables may be visualized in relation to circles or hyperbolas but the same concepts are inadequate when dealing with complex variables. After all, it is difficult to visualize a "complex angle". A simple and useful interpretation of these hyperbolic functions may be gained from their equivalent exponential forms plus the physical significance of these exponential quantities in the transmission-line theory. It is hoped that this interpretation may be found useful by those engineers who must always "see a picture of things".

Both the trigonometric and hyperbolic cosines may be represented by the same general exponential form

$$\frac{e^{\gamma} + e^{-\gamma}}{2} \quad (1)$$

For real variables, the only difference between these two functions is that for the hyperbolic cosine γ is a real quantity, while for the trigonometric cosine γ is a pure imaginary quantity. Sometimes it is claimed that this exponential expression for the cosine lacks physical significance, but this criticism does not seem justified in view of the very lucid interpretation which has been presented in a recent text.* This interpretation will be outlined briefly, as it forms the basis for the present interpretation of hyperbolic functions of complex variables.

The relations

$$e^{j\omega t} = \cos \omega t + j \sin \omega t \quad (2)$$

and

$$e^{-j\omega t} = \cos \omega t - j \sin \omega t \quad (3)$$

are well known in electrical engineering. $e^{j\omega t}$ is merely a unit vector in the complex plane, rotating in a positive (counterclockwise) direction with an angular velocity of ω radians per second. At any instant, its projection on the real axis is $\cos \omega t$ and its projection on the imaginary axis is $\sin \omega t$. The square root of the sum of the squares of these real and imaginary components gives the magnitude of the vector and always must equal unity. Similarly, $e^{-j\omega t}$ may be interpreted as another unit vector rotating in the negative (clockwise) direction with the same angular velocity.

Since

$$\cos \omega t = \frac{e^{j\omega t} + e^{-j\omega t}}{2} \quad (4)$$

the cosine is given by half the sum of these two vectors which rotate in opposite directions. This is illustrated by figure 1, which shows that the imaginary components of these two vectors always cancel

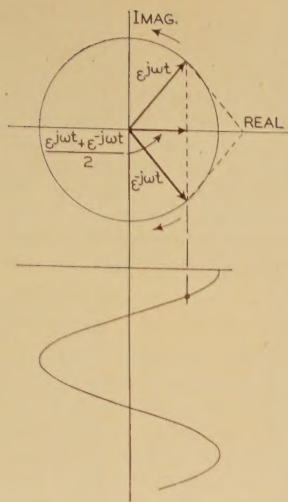


Figure 1

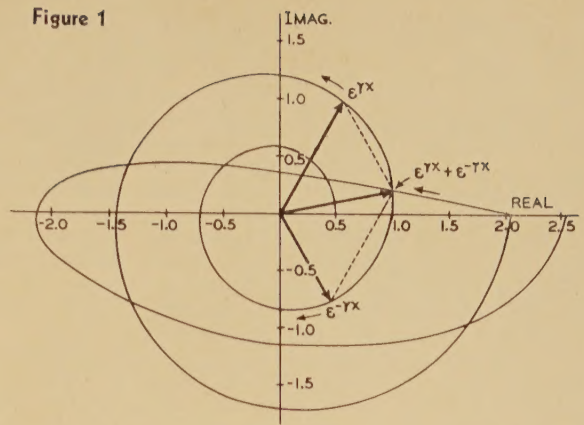


Figure 2

each other, while their real components add to generate the familiar cosine wave. This is merely a graphical addition of equations 2 and 3.

For complex variables

$$\cosh (\alpha + j\beta)x = \frac{e^{(\alpha + j\beta)x} + e^{-(\alpha + j\beta)x}}{2} = \frac{e^{\alpha x} e^{j\beta x} + e^{-\alpha x} e^{-j\beta x}}{2} \quad (5)$$

In this, $e^{(\alpha + j\beta)x}$ is a rotating vector whose length increases exponentially according to $e^{\alpha x}$ and whose direction is given by $e^{j\beta x}$. Consequently, the locus of this vector is an exponentially increasing spiral in the complex plane, starting from the point $1 + j0$, when x is zero. Similarly, $e^{-(\alpha + j\beta)x}$ rotates in the negative direction and its length decreases exponentially. Its locus is an exponentially decaying spiral.

Figure 2 shows the graphical addition of these two vectors. Unlike figure 1, the locus of the sum of these two vectors does not follow the real axis, because their imaginary components no longer cancel each other completely. The locus of the sum, $2 \cosh (\alpha + j\beta)x$ starts from $2 + j0$ and gradually approaches the locus of $e^{(\alpha + j\beta)x}$ as $e^{-(\alpha + j\beta)x}$ vanishes for large values of x . The locus of the hyperbolic cosine, which is half this sum, has the same shape but only half the magnitude.

For the hyperbolic sine

$$\sinh (\alpha + j\beta)x = \frac{e^{(\alpha + j\beta)x} - e^{-(\alpha + j\beta)x}}{2} \quad (6)$$

A similar construction may be employed to give the locus of the difference of these two vectors, as shown in figure 3. The subtraction is performed by first forming the negative of the decaying vector, by a 180-degree rotation, and adding this to the expanding vector. The locus starts from the origin and again approaches $e^{(\alpha + j\beta)x}$ as $e^{-(\alpha + j\beta)x}$ vanishes.

Other hyperbolic functions, such as the hyperbolic tangent, are defined in terms of these two basic functions, so need not be considered here.

The remaining step is to show the correlation between transmission-line theory and these exponential loci. The voltage at any point along the line is given by

$$E = E_s \cosh \gamma x - I_s Z_0 \sinh \gamma x \quad (7)$$

where E is the vector voltage, $E_m e^{j\omega t}$, at any

point x miles from the sending end of the line. E_s and I_s are the vector voltage and current at the sending end of the line. Z_0 is the characteristic impedance of the line. γ is the propagation constant, given by

$$\gamma = \alpha + j\beta \quad (8)$$

where α is the attenuation constant in nepiers per mile and β is the phase constant in radians per mile.

Throwing equation 7 into its exponential form and collecting terms,

$$E = \frac{E_s + I_s Z_0}{2} e^{-(\alpha + j\beta)x} + \frac{E_s - I_s Z_0}{2} e^{(\alpha + j\beta)x} \quad (9)$$

This shows that the voltage at any point along the line consists of the sum of a transmitted and a reflected voltage wave. The transmitted wave decreases exponentially from its sending-end value, $\frac{1}{2}(E_s + I_s Z_0)$, and its phase angle lags that of the sending-end voltage by $-\beta x$ radians. The reflected wave increases exponentially with distance from the sending end, which is equivalent to saying that it decreases exponentially with distance from the receiving end of the line, its point of origin. This reflected wave has a value $\frac{1}{2}(E_s - I_s Z_0)$

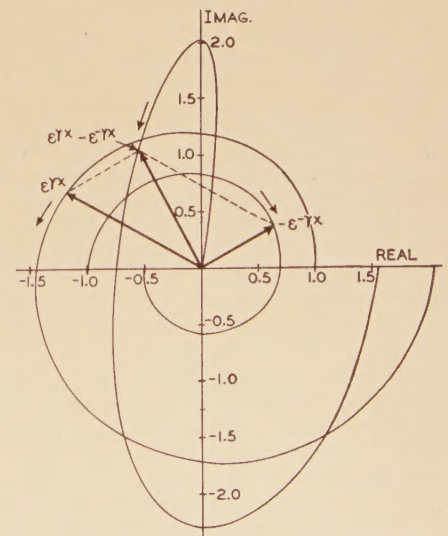


Figure 3

*ELECTRIC CIRCUITS, Members of the Staff, Department of Electrical Engineering, Massachusetts Institute of Technology. John Wiley and Sons, Inc., New York, N. Y., 1940, pages 203-07.

at the sending end of the line, which generally is much smaller than the value of the transmitted wave. The phase angle of the reflected wave at any point leads that of the sending end voltage by $+\beta x$ radians.

This exponential form of the transmission-line voltage equation lends itself to physical interpretation in terms of the transmitted and reflected waves on the line much more readily than the more familiar hyperbolic form of equation 7, and many other interesting conclusions may be obtained from it. The hyperbolic form is more convenient for making calculations, especially when tables or charts of these functions of complex variables are available, because each function is multiplied only by E_s or by $I_s Z_0$, instead of by half the sum or difference of these complex voltages. In other words, the general acceptance of the hyperbolic form of the transmission equations probably has resulted rather from reasons of mathematical expediency than as an aid to their physical interpretation in terms of reflection phenomena.

Even so, equation 5 shows that $\cosh(\alpha + j\beta)x$ may be regarded as half the sum of a reflected wave $e^{(\alpha + j\beta)x}$ and a transmitted wave $e^{-(\alpha + j\beta)x}$, these waves being equal when x is zero. Similarly, equation 6 may be regarded as half the difference between these reflected and transmitted waves. The graphical interpretations given in figures 2 and 3 therefore may be regarded as simple vector diagrams showing the loci of the sums and differences of reflected and transmitted waves which happen to be equal at the sending end of a line, where x is zero.

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Books Received •

Modern Plastics Catalog, 1941. The 1941 catalog and directory published by *Modern Plastics* magazine endeavors to present complete information on all phases of the plastics industry. Issued for the first time in its present form, the volume is divided into eight sections: plastics engineering, materials, molding and fabricating, machinery and equipment, laminates, plastic coatings, synthetic fibers, and an index and directory section which includes a bibliography and chapter on nomenclature. Charts on plastics properties, solvents, and plasticizers are included, the latter two for the first time. Copies of the 476-page 9-by-12 volume with special plastics cover may be obtained from the Breskin Publishing Corporation, 122 East 42d Street, New York, N. Y.; price \$3.50.

Index to ASTM Standards. The latest edition of the "Index to ASTM Standards, Including Tentative Standards," recently issued, contains information on the society's 952 standards as of December 1, 1940. Copies of the 172-page publication may be obtained without charge on written request to ASTM headquarters, 260 South Broad Street, Philadelphia, Pa.

"Rural America Lights Up." The stipulated purpose of this book by Harry Slatery, is "to describe the evolution of rural electrification in its relation to the economic security and well being of American agricultural life; not neglecting the important part it must play in any program dealing with national defense." Published by National Home Library Foundation, Washington, D. C.; $4\frac{1}{2}$ by $7\frac{1}{4}$ inches, 142 pages, flexible cardboard binding; price 25 cents copy.

"Cadiz to Cathay". Subtitled "the long struggle for a waterway across the American isthmus", this 550-page study by Miles P. DuVal traces and reconstructs the events leading to the creation of the Panama Canal, crediting each nation concerned with its part in that development. The texts of pertinent treaties are appended, and there is a reference list of official and general publications and other material. Stanford University Press, Stanford University, Calif., price \$5.00.

"Little Bits About Big Men". Anecdotes about business leaders and men in public life which were collected by B. C. Forbes through personal acquaintance or during interviews are assembled in this volume. Among those mentioned are many well-known Institute members. B. C. Forbes Publishing Company, New York, N. Y.; price \$2.50.

"Unheeded Warnings". Newspaper contributions, addresses, and letters to the President and members of Congress by D. S. Snell (A'24) on international events and their relation to the future of the United States have been compiled in this volume, published by the author. Price per copy, \$2.00.

The following new books are among those recently received at the engineering Societies Library. Unless otherwise specified, books listed have been presented by the publishers. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books in question.

PRACTICAL DESIGN OF SMALL MOTORS AND TRANSFORMERS (Electrical Engineer Series, volume II). Edited by E. Molloy. Chemical Publishing Company, New York, 1940. 176 pages, illustrated, 8 by 5 inches, cloth, \$2.00. Practical information on the design, construction, and rewinding of small motors, dynamos, and power transformers. The simplicity of the calculations and the many photographs, diagrams, and tables of working data make the book particularly useful to the general worker.

SCIENCE IN INDUSTRY. By A. M. Low. Oxford University Press, New York, 1939. 160 pages, illustrated, 9 by $5\frac{1}{2}$ inches, cloth, \$1.75. Describes some of the more important ways in which scientific discovery has influenced the course of industrial development and affected our ordinary life. Topics covered include refrigeration, metals, coal and its by-products, transport, and printing. For the general reader.

SOUND. By E. G. Richardson. Third edition. Longmans, Green and Company, New York; Edward Arnold and Company, London, 1940. 339 pages, diagrams, etc., $8\frac{1}{2}$ by $5\frac{1}{2}$ inches, cloth, \$5.25. Attempts to give the student the results of recent experimental research, and should be useful to research workers for reference, for it supplements the descriptions of important work by copious reference to original papers. This edition has been carefully revised, especially in the chapters upon impedance, supersonics, and sound reproduction.

TABLES OF SINES AND COSINES FOR RADIAN ARGUMENTS. Prepared by the Federal Works Agency, Works Project Administration

for the City of New York, as a report of Official Project No. 765-97-3-10; A. N. Lowan, technical director; conducted under the sponsorship of the National Bureau of Standards, Washington, D. C., 1940. 275 pages, tables, 11 by 8 inches, cloth, \$2.00. The major part of this fourth volume of a special series of mathematical publications consists of a table of values of $\sin x$ and $\cos x$ to eight decimal places at intervals of 0.001 from 0.000 to 25.000. Supplementary tables give values of $\sin x$ and $\cos x$ to various numbers of decimal places for other ranges and intervals, values of $p(1-p)$, and conversion tables from radians to degrees and vice versa.

GEOPHYSICAL PROSPECTING FOR OIL. By L. L. Nettleton. McGraw-Hill Book Company, New York, 1940. 444 pages, illustrated, 9 by 6 inches, cloth, \$5.00. While there is a voluminous periodical literature upon the subject, this appears to be the first connected presentation, in a single volume, of the principles and practice of modern oil prospecting by geophysical methods. Intended for students or lay readers, rather than for specialists, the subject matter selected and its presentation are based upon practical experience in the use of geophysical methods. Gravitational, magnetic, and seismic methods are discussed at length; electrical prospecting and well-logging methods, miscellaneous prospecting methods, and operations in wells described briefly. A section is devoted to interpretation of geophysical surveys.

TECHNICAL DRAFTING. A Text and Reference Book on Graphics. By C. H. Schumann. Harper and Brothers, New York and London, 1940. 793 pages, illustrated, $9\frac{1}{2}$ by 6 inches, cloth, \$3.50. Designed not only as a comprehensive textbook on engineering drafting but also as a professional reference book. The first part presents the elementary principles of the subject. The second part goes intensively into commercial practice in the various branches of engineering, including welded construction and both architectural and topographical drafting.

TECHNICAL DRAWING. By F. E. Giesecke, A. Mitchell, and H. C. Spencer. Second edition. Macmillan Company, New York, 1940. 687 pages, illustrated, 9 by 6 inches, cloth, \$3.00. Covers the science of technical drawing, including such special applications as architectural and topographic work and the reproduction of drawings. Among several new chapters in this edition is one on welding representation. There are many practical examples and problems, and lists of symbols, data tables, specifications, and a bibliography are appended.

THE UNITED STATES PATENT SYSTEM. By J. A. Diener. American Society for Metals, Cleveland, Ohio, 1940. 73 pages, diagrams, etc., 9 by 6 inches, fabrikoid, \$1.00. Contains three lectures presented to the Chicago chapter of the American Society for Metals. The distinctive features of the United States patent system are described, reasons for their establishment and continued use presented, and controversial issues explained. Recent legislative activity is discussed. Bibliography.

TELEVISION TODAY AND TOMORROW. By S. A. Moseley and H. J. Barton-Chapple, with a foreword by J. L. Baird. Fifth edition. Pitman Publishing Corporation, New York, 1940. 179 pages, illustrated, 9 by $5\frac{1}{2}$ inches, cloth, \$3.00. The history of television is briefly reviewed, its general principles are discussed, and equipment and processes are described. The subject of big-screen television is considered at some length, and several special television methods likely to be of importance in the future are described. A glossary of terms is appended.

ATM (Archiv für technisches Messen). 107, 108, 109, 110; May, June, July, August 1940. R. Oldenbourg, Munich and Berlin, pages T49-T96, illustrated, May 12 by 8 inches; June, July, August, 12 by $8\frac{1}{2}$ inches; paper, 1.50 rm each. Four numbers of a monthly publication containing classified articles upon various types of apparatus and methods for technical measurements. Certain numbers also contain descriptions of specific instruments manufactured by German companies.

MACRAE'S BLUE BOOK AND HENDRICK'S COMMERCIAL REGISTER. 48th edition, 1940-41. MacRae's Blue Book Company, Chicago and New York, 1940. 3,623 pages, illustrated, $11\frac{1}{2}$ by 8 inches, cloth, \$15.00. The new edition of this directory follows the plan of preceding ones. It includes an alphabetic list of manufacturers, producers, and wholesalers, with the addresses of branch offices; a minutely classified list of products, with an extensive index; a list of towns of 1,000 or more population, with their trade facilities and railroad connections; and a list of trade names.

TREATISE ON ADVANCED CALCULUS. By P. Franklin. John Wiley and Sons, New York, 1940. 595 pages, diagrams, etc., 9 by 6 inches, cloth, \$6.00. Although the reader is assumed to be familiar with the fundamental methods of the calculus, these are briefly reviewed together with the prerequisite parts of algebra and analysis. The text then continues with an exposition of infinitesimal calculus, including those parts of the theory of functions of real and complex variables which form the logical basis of the infinitesimal analysis and its applications to geometry and physics. Exercises accompany each chapter.